ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

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Root Starches Other than Those of White and Sweet Potato

Such starches are not produced in the United States but are imported. Tapioca, from cassava roots, constitutes about 86% of them and is particularly valued in the food and adhesive industries. Sago from the pith of palm trees and cycads is used primarily as an adhesive; arrowroot from a rhizome as a food starch.

O. B. WURZBURG

National Starch Products, Inc., 270 Madison Ave., New York 16

Tapioca

Tapioca is the most important root starch imported into this country. In 1950, imports of the crude and refined starch or flour totalled 111,227,458 pounds. During the past 20 years the imports have averaged about 190,000,000 pounds per year with a low of 48,403,185 in 1944 during the war and a high of 432,857,738 pounds in 1937. Its position in respect to other imported starches is amply demonstrated by the fact that last year it constituted about 86½% of our total starch imports.

Manihot, the plant source for tapioca starch, is a native of the Americas. It was under cultivation in the Caribbean Islands and parts of Central and South America when the first Spanish explorers came to the New World. Subsequently it was spread to Africa, Malaya, Java, the East Indies, etc., until today it may be found throughout the tropics, where it is an important part of the natives' diet.

The starch is extracted from the roots, and the plant has a variety of common names, depending on location; in the Netherland East Indies it is called " cassava "; in Brazil, " mandioca " or " manioc "; and in Cuba, " yuca ".

The plant is very shrubby, with palmate leaves somewhat resembling those of the horse chestnut. It grows to heights of ten or 12 feet and has roots growing from the main stem just below the surface. They average about 15 inches in length and about five inches in diameter, although some reach a much larger size.

There are two main varieties: *Manihot utilissima* Pohl, also known as the " bitter variety ", and *Manihot palmata*, known as the " sweet variety ". Both contain traces of a glucoside, phaseolunatin, which yields deadly hydrocyanic acid in processing. In the sweet variety this is located primarily in the outer layer and is removed by peeling. In the bitter variety, which contains somewhat larger amounts, it is not so localized, but is easily extracted by washing.

Both types, after being properly prepared to remove the hydrocyanic acid, are used as food by the native population. The bitter variety, however, is preferred for starch production, since its roots usually contain more starch (up to 30% total starch).

Manihot may be planted at practically any time of the year. The age of the roots used for starch production may vary from ten months to two years, the highest quality starch being obtained from two-year-old roots. However, in order to get better yearly yields per acre, younger roots are frequently used.

Roots for processing into starch are supplied by individual farmers or large plantations which are usually operated by the mills. Unlike maize in the United States, manihot roots cannot be stored for very long periods without spoilage unless they are cleaned and thoroughly dried immediately after harvesting. This has been practiced in some instances in the Netherland East Indies, where labor is cheap, but normally it is not feasible economically nor conducive to the best quality starch. Consequently it is important to coordinate gathering of the roots and processing so that there is a minimum time (preferably less than a day) between operations. This has resulted, on the one hand, in a trend toward the establishment of many small mills close to the farms, and, on the other hand, in a trend by the large mills toward a plantation system.

The starch content of the roots varies from about 15% to over 30%, depending upon their variety and condition. This may be contrasted with 12–20% for potatoes and about 60% for maize. In addition to starch, the roots contain moisture, sugars, about 1% protein, about 1% fiber and approximately ½% fats and ½% ash.

Most mills follow the same basic processing pattern. It is a wet milling process, water being used to convey the starch throughout the system and to wash away impurities. Briefly, it involves washing the roots to remove foreign matter, destroying their cellular structure so as to liberate the starch, screening off the fibrous material, separating the starch from the water-soluble impurities and protein by gravitational means, and drying.

In some mills the whole operation is very crude, involving hand-driven graters or rasps for pulping the roots, small settling basins for separating the starch, and large pans in which the settled starch is spread for drying in the sun. On the other hand, in many modern mills efficient mechanized equipment is used. Thus cleaning and peeling are carried on in large horizontal rotary washers equipped with helical shovels that move the roots forward through the washer. Water is sprayed in during the process, washing out the dirt and peelings through perforations or slots in the washer. On emerging from this washer, the cleaned peeled roots are passed through a power-driven rasp or hammer mill which grinds the roots into pulp then carried by a stream of water over a series of vibrating screens. The fibrous matter is retained on the screen and washed away, while the starch milk passes through the screens onto starch tables. These are long narrow troughs (one to two feet wide and 80 or more feet long) which are inclined at an angle small enough to permit most of the starch to settle out, yet large enough to prevent settling of the lighter protein matter. Some mills use settling basins which are large shallow tanks capable of holding a day's production. The starch milk is pumped into these basins, the heavier starch settling to the bottom, while the protein and lighter impurities remain at the top, and the water-soluble material stays in solution. After settling, the water is decanted, the top layer of the sediment is scraped off, and the remaining starch is surface-washed. The settled starch is either dug out and dried or suspended, filtered, and dried in kiln dryers, vacuum dryers or continuous automatic tunnel type dryers to a moisture content of 10–14%. It may be packed as is, in a coarse form, or ground to a fine powder before packing.

In some cases a bleaching treatment with bisulfite is used prior to drying in order to whiten the starch further. Since some impurities in the processing water often have a deleterious effect on the starch quality, the more progressive mills use pretreated water in the milling.

Variations in the condition of the roots and in processing equipment and technique result in starches of widely differing quality. Much of the tapioca brought into this country bears a brand name or some sort of markings characteristic of the mill or importer. These starches are usually priced according to quality, currently ranging from about $6.50 to $8.00 cwt. for the lowest and highest grades, respectively.

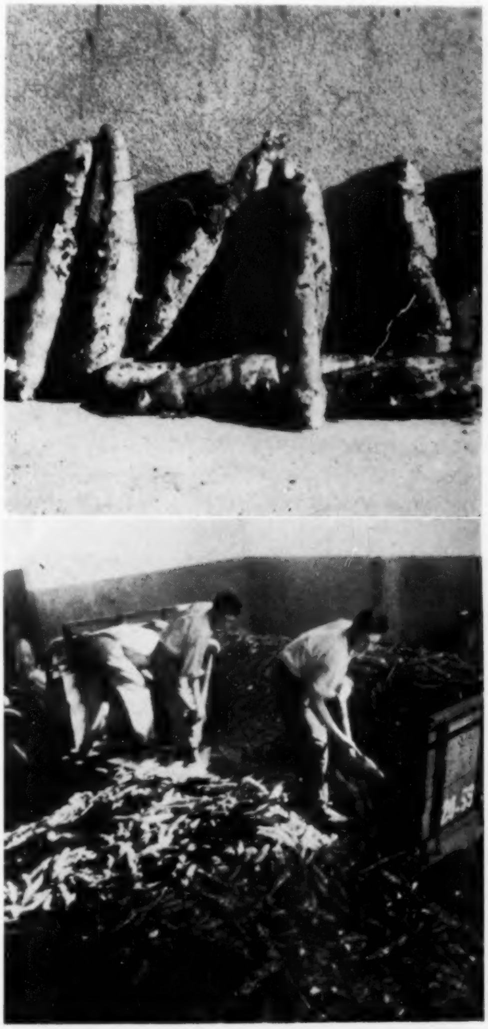
The relative quality of a given tapioca starch is determined by the color, odor, grind, cleanliness, moisture content, pulp, acidity, ash and viscosity or body when cooked in water. A top grade starch is a pure white powder with 11–13.5% moisture, free of all dirt, black specks and any foreign or musty odors. It does not contain any pulp or fibrous matter, has negligible ash and cooks at 4% concentration in water to a heavy, cohesive, fairly clear sol which does not change appreciably on cooling. In contrast, corn starch cooks thinner and on cooling forms an opaque gel.

While experience has taught the users of tapioca that certain brands are fairly consistent in quality, he must still keep close check on each shipment.

Before World War II the great bulk of imports came from the Netherlands East Indies, with negligible amounts (less than 10%) from Santo Domingo and Brazil. During the war, however, the supply from the East Indies was cut off and this country turned to Brazil. Through the cooperation of millers, brokers and users, and modernization of milling equipment, Brazilian tapioca has helped fill the gap in our domestic requirements, and today it constitutes a sizable portion of our total imports.

Of academic interest is the fact that tapioca was milled in Florida some 50 years ago. However, the Florida tapioca was unable to compete with foreign production and has since passed out of the picture.

When examined under a microscope, tapioca starch granules resemble truncated ovals. They range from about five to 35 microns in diameter. Some idea of their size may be had when one



Cassava, or manihot, roots prior to processing.

realizes that there are 25,400 microns in one inch. The granules have a centrally located hilum which resembles a black spot. Under polarized light they show very distinct polarization crosses which intersect the hilum.

The granules swell on being heated in

water to give a sol having the typical root starch characteristics of a cohesive, rubbery body, good clarity and stability.

Tapioca is used in many industries which utilize corn starch, and possesses certain unique characteristics which give it definite advantages. For this reason its marketability is not entirely dependent upon its maintaining a price competitive with corn. Many consumers are willing to pay a premium for tapioca-based products. These include bakers who desire the superior clarity and body characteristics of certain modified tapioca starches for use in pie fillings, pail fillings, etc. Envelope makers often prefer the superior machining properties and film characteristics of tapioca canary dextrines. Adhesive manufacturers are attracted by the superior film, tack and stability of tapioca in some of their formulations. Food manufacturers find it of interest in puddings, where it is best known to the American family in the form of pearl tapioca. In general, tapioca is of particular interest wherever a starch having better clarity and stability than corn starch is needed.

It should be kept in mind that the hybrid waxy corn starch, amioca, as well as waxy sorghum starch, has many of the advantages of tapioca. To maintain its position, tapioca must remain competitive with these starches. It has done this in the coastal regions, and as long as it continues to do so, sizable amounts should be imported annually.

Sago

Strictly speaking, sago is not a root starch. However, it is usually grouped with the root starches because of its similarity in properties. Nearly six million pounds of it were imported in 1950. It is obtained primarily in the Netherlands East Indies from the pith in the trunk of palms and cycads which include the following species: *Metroxylon Rumphii* Mart. (*Sagus Rumphii* Willd.), *M. laeve* Mart., *M. Sagus*, *M. Koenigii* Rumph., as well as *Cycas revoluta* L. and others.

The trees usually grow wild in marshy lands, although some are cultivated. They grow to heights of 20–30 feet and have trunks which range up to two feet in diameter and have a hard outer layer about one inch thick. Within there is a soft, white, cheesy pith comprising the starch and fibrous matter. The starch is deposited here in large amounts during certain periods for use during the fruiting season when the tree develops a flower spike. The trees attain maturity in 15–20 years, when they contain the maximum amount of starch. One mature palm tree may yield as much as 800 pounds of starch. Since the flower spike, if allowed to develop, consumes most of the starch in the trunk, it is important to cut the tree down before it develops.

The manufacture of sago is very simple and often quite crude. The trees are felled and split lengthwise. The starchy pith is then removed, chopped up and grated to a powder. This is then kneaded with water over a strainer which retains the fibers and permits a slurry of starch in water to pass through. Thereafter the processing is similar to that used for tapioca, although it is generally on a cruder scale.

The finished starch is usually quite impure, being tan-colored and very fibrous. Its crude condition has been a drawback to its employment in many industries. However, it has certain properties which make it particularly desirable in certain adhesives, sizes and foods. At one time in the late 30's appreciable amounts were imported into this country for further refining and processing into thin boiling starches and dextrines.

Granules of sago are fairly large, ranging from 20 to 60 microns. They are oval and many are slightly truncated. Their hilum is located toward

one end and they have a distinct but irregular polarization cross which intersects at the hilum.

Arrowroot

The term " arrowroot " is sometimes loosely applied to starches from a number of plant sources. Frequently it is confused with tapioca. However, true arrowroot starch is a distinctive type, having granules which range from 15 to 70 microns in length and are oval, being quite different from those of tapioca.

It is sometimes called " West Indies arrowroot " and is obtained largely from St. Vincents, British West Indies, nearly five million pounds of it being imported in 1950. The starch is manufactured from the roots of a rhizome—*Maranta arundinacea* L.—which has stems one to two feet long with oval lanceolate leaves. It bears white flowers arranged in twin clusters. Its roots are covered with scales which, unless removed in milling, impart a bitter taste to the starch. Although the total starch content of the roots is comparable to that of *Manihot,* the actual yield is considerably less because their cell structure is very tough.

The milling process is similar to that used for making tapioca except for the fact that the root scales must be thoroughly removed and the roots must be given a more intensive milling or maceration to break down their very tough cellular structure.

The finished starch cooks in water to give a product which is similar to some grades of tapioca. In general, however, the cooked arrowroot tends to have a shorter, less cohesive type of body than tapioca. It is used primarily for food and dietetic uses, where it enjoys a reputation for smoothness and palatability.

Since the yields are low and processing costs relatively high, arrowroot starch sells at a considerably higher price than other commercial starches. The annual imports are small but fairly consistent. It is doubtful, however, that arrowroot will ever be a particularly significant starch in the economy of this country.

Utilization Abstracts

Sweet-Potato Starch. Sweet-potato starch has been produced under the name of " Brazilian arrowroot ", and " for many years it has been manufactured in Japan, where it is used in laundries, for sizing textiles and paper, for food, and in cosmetics ". " Pioneer experimental work on sweet-potato starch in the United States was begun at the South Carolina Agricultural Experiment Station in 1895 and was continued for about 15 years ". Additional experimental work has been carried on at various times since then, and " in 1934 the Federal Emergency Relief Administration established a small starch plant at Laurel, Miss., to ensure a market for sweet potatoes in that area . . . ". Operations were suspended in 1944. In 1945 and 1946 a similar plant was operated at Clewiston, Fla., but that, too, was unprofitable and discontinued. Some of the starch manufactured at these factories went into textile sizing and laundries, some into prepared food specialties, some into dry batteries, and some into the manufacture of dextrin. But sweet-potato starch production and utilization await the solution of many technical problems before an industry can really be developed. (F. H. Thurber, E. A. Gastrock and W. F. Guilbeau, *U. S. Dept. Agr., Yearbook 1950–1951*).

Kenaf in Florida. Kenaf (*Hibiscus cannabinus*), the relatively new fiber crop that is being grown in Cuba to free that island from dependence on imported jute from India and Pakistan for manufacture into sugar bags, was grown and harvested in Florida for the first time in 1951. (R. V. Allison, *Chemurgic Digest 10(11): 10. 1951*).

Adlay or Job's Tears—*A Cereal of Potentially Greater Economic Importance*

The bony fruits of this grass have for centuries been used in the Orient, ornamentally when polished and as food when ground into flour. The plant is today acquiring importance in Brazil as a fodder and forage crop, and the grain is being used there as poultry and cattle feed.

REIMAR v. SCHAAFFHAUSEN [1]

Introduction

In recent years in several countries there has been an increasing interest in the cultivation of the cereal adlay (*Coix Lacryma-Jobi* L.). Information about this plant is to be found chiefly in foreign language publications of several countries, and an attempt is here made to give a brief review of some of this literature.

A particular variety of adlay was introduced into Brazil a few years ago and is now successfully cultivated there. After first considering adlay in general, the advantages, analyses and cultivation of this new variety will be described because it may in the future become an important crop also for other countries.

Structure, Species and Varieties

Several species have been described as constituting the grass genus *Coix* (pronounced "ko iks"), but most authors admit only two or three, of which *C. Lacryma-Jobi* is the best known. It is a robust, broad-leaved, loose-growing, branched grass, four to six feet tall, and is distinguished, as are all members of the genus, by inflorescences made up in part of hard, globular or oval, hollow, bead-like structures, one of which is developed at the end of each peduncle from a leaf sheath. These grasses are monoecious, and the staminate spike projects from an orifice in certain of the beads, whereas the pistillate flowers are inclosed in other beads, only the styles projecting.

Several named varieties of *C. Lacryma-Jobi* have been recognized in India (19) and the Philippines (47), and in Ceylon three seed-color varieties—yellow, purple, white—are planted separately. The protein content of all these varieties is much lower than that of the brown-seeded new variety discussed later, and analyses of the three Celanese varieties have been published (1). In one examination (22) of 47 samples of *Coix* from eastern Asia and of three from America, the seeds were found to vary greatly in size, shape, color and hardness of shell. Plants raised from them were a little less variable, some having numerous stalks and narrow leaves, while others with a few thick culms and long broad leaves had more the appearance of maize or sorghum. Of the 50 samples, 14 were found to contain seed with waxy endosperm, and 13 of the 14 were of the soft shell type but differed greatly in other respects. In addition to differences in endosperm texture, seeds of *Coix* differ also in the color of the pericarp. Those of most hard-shelled forms have a dark red pericarp, while the pericarp color of many soft-shelled seeds is very light brown.

[1] Caixa Postal 12633, Sto Amaro, São Paulo, Brazil.

Nomenclature

The generic name *Coix* may be regarded as of Greek origin (41), for it occurs in the works of the philosopher Theophrastus who, in the fourth century before Christ, applied the name to a reed-like plant which might have been a form of our modern *Coix*. It appears that the plant described by Pliny in the first century after Christ as " lithospermum " was a form of *Coix*.

The common English name, Job's tears, is of course a literal translation of the specific name bestowed by Linnaeus on this plant, but where Linnaeus got the idea is probably not known. The Arabs called the seed " damu Daud ", or " Tears of David ", and substitution of Job for David somewhere along the line probably accounted for the change. In Ceylon the plants are known as " kirindi ", and in 1920 Wester (45) proposed the euphonious Philippine name of these plants, " adlay ", as an English vernacular designation for the edible forms. It should be pronounced " adly ", with the accent on the first syllable.

History, Geographical Distribution

According to Pierris (26), the edible grain of adlay was cultivated in India 3000 to 4000 years ago. It was known to the ancient Arabs, who introduced it to the West, and was grown in ancient times in China, Japan and tropical countries. Watt (42) states that the edible forms were grown in India, Tonkim (China), Malaya and Japan, and he says: " Were a statement prepared of the geographical features of interest in the cultivated plants of British India, *Coix* would have to be commented on as characteristic of the tract of country that stretches east by south from Nagpur to Sikkim, Assam, Burma, the Malaya and China, and be regarded as an important food grain with some of the most ancient aboriginal inhabitants, especially those of Mongolian origin ".

Romanet du Cailleaud (29) mentioned that in the first century after Christ the Chinese general Ma-Yuen conquered Tonkim and thought so highly of the grain bo-bo, the y-dzi of the Chinese, that he brought back several carloads of seed, thus introducing it to China. Seed of the y-dzi of Tonkim, received at Kew Gardens in 1892, was found to be so similar to that of *Coix gigantea* that the Kew Bulletin classified it in 1893 under that name.

Uses

Ornament. The hard bony fruits of *Coix* have been used long and extensively in the Orient for ornamental purposes in rosaries, necklaces and draperies. Watt states that they occur in many colors, but on cultivation lose their hardness and become softer shelled, and therefore canot be cultivated on a large scale to satisfy the European demand. To this point Kempton gives another explanation, as will be noted later.

Human Food. Wester, who about 1920 made extensive studies of the many varieties in the Philippine Islands, was chiefly interested in their use as human food. Analyses of the grain were made and compared with those of other cereals. The protein content was found to be similar to that of wheat, and its biological value higher. Wester succeeded in making flour out of adlay, though with difficulty on account of a lack of suitable machinery. The baking results in making biscuits were excellent and highly praised by all who tried them. For human consumption the hulled grain can be used in all the ways that rice is used. The advantage of adlay over other cereals used as food on the farm lies in the possibility of using it without first having to send it to mills for processing. It can be hulled easily in machinery for hulling rice, or by hand by pressing it over a sieve, thus breaking the softer hulls. Prepared in this way it does not lose its vitamine content, as does rice through

polishing. It therefore offers a valuable food for the often undernourished populations of rural districts.

In Brazil it was required by law around 1939 to mix flour made of imported wheat with flour of manioc (*Manihot esculenta*), and intensive planting of adlay was advocated to use its flour for this purpose. Good bread could be made out of a mixture of wheat flour with 30% of adlay flour, as well as biscuits, but adlay flour has not been used extensively for this purpose. The reasons probably are that adlay has not been planted on a large scale and that mills have consequently been reluctant to make necessary adaptations in their machinery for milling it. Farmers, on the other hand, have been reluctant to plant a new cereal on a large scale without guaranty of a steady market.

The edible forms of adlay have been used also in other ways. Pierris states that of all cereals grown in Ceylon, adlay has been found to be the best substitute for staple rice. It has been proved to be more wholesome than either wheat or rice, as it contains a greater proportion of fat and protein. The grain was never popular in India, in view of the varied assortment of other cereals there, but in times of scarcity it has been cultivated extensively as a food crop.

The Chinese use the grain in soup, the same as barley is used in Europe. In Japan it is employed to make a refreshing drink, called "dzu", which tastes something like butter milk and cider.

Medicinal. *Coix* is also referred to as having medicinal properties. It is said to purify the blood and to have diuretic properties. The people of Tonkim call it the plant of life and health. In 1885 seeds were sold in pharmacies in Bombay under the name of "kassai-bij". Only native forms were credited with medicinal properties.

Forage and Fodder. It is as a forage and fodder crop that adlay finds its principal use today. Since it has a greater protein content than corn which is grown on every farm as feed for cattle and poultry, and since it is well liked by all farm animals, it can be used for that purpose instead of corn, and the latter can be disposed of on the market.

After the plant has been cut down for harvesting, it tillers, and during the dry season the newly grown leaves are fresh and green, making an excellent fodder for cattle and protecting the soil against erosion and drying out by the sun.

If there is sufficient rainfall, a second harvest of grain can be obtained, but in the climate of São Paulo, where cultivation of adlay has been increasing during recent years, there usually is not sufficient rainfall to make a second harvest economically interesting. In the absence of sufficient moisture many grains will be hollow.

Adlay flowers over a period of about one month. The first seed is ripe when the crop is still partially green. When most of the seed is ripe, the plant dries. If the plant is cut when most of the seed is ripe but before the plant has dried, the leaves after threshing can be used for silage. If the plant is harvested late, the dry plant makes good compost.

Why Has Adlay Not Yet Become a Staple Food?

Though *Coix* has been known and used for thousands of years and has many properties which recommend its cultivation, it is not yet to be considered of economic importance. Wester accounts for this in the following remarks (46): "Many people have expressed incredulity relative to the cereal value of adlay, contending that if it had the merits claimed they would have been discovered long ago and the grain would have become widely grown and used as a food stuff before now".

"However, the previous rejection of adlay as a staple food apparently has

FIG. 1 (*Upper*). The author in a Brazilian plantation of adlay.

FIG. 2 (*Lower*). Inflorescences of adlay, showing the bead-like structures which enclose the flowers and which for centuries have been used in the Orient for ornamental purposes.

been due not to an intrinsic inferiority of the grain, but to peculiar features which have made it inferior to rice as grown by primitive people, objections which are removed by advent of modern machinery and better knowledge of the grain. Of course, the long growing season is admittedly a drawback, though to some extent this is compensated for by the fact that adlay is less subject to attacks of locusts than rice and corn. Like rice, adlay originated in tropical Asia. But rice possessed the great advantage of being the better keeper of the two, which, outside of its food value, has probably been the most potent factor in making it the most important of all tropical grains . . . . Then, rice is far better adapted to preparation of food by the mortar and pestle—the original grain mill invented by man—method of hulling the grains than adlay, first because when the pestle is brought down on smooth round adlay grains, these fly out of the mortar in all directions, whereas rice does not; second, because the kernel of adlay is softer than that of rice and is more easily broken in the course of hulling, resulting in more waste than in the hulling of rice, which is hard and flinty. With the introduction of modern machinery these disadvantages disappear".

The foregoing comments may explain why adlay up to 1921 was not cultivated extensively. Since then, as a result of propaganda, the grain has been tried in Brazil, Bolivia, Costa Rica, Ceylon and in other countries. In spite of modern machinery, however, which could have hulled the grain without difficulty, it has not become an important staple food. The reasons for this may be the following factors:

a) Difficulties in changing food habits.

It is a known fact that most people are very conservative in their food habits. New food products usually become introduced only by intensive propaganda. Pierris stated in 1936 that *Coix* is an excellent substitute for rice, and is more nourishing. It can be boiled whole or partly broken. The flour is an admirable substitute for rice flour for the preparation of articles of food such as hoppers and milk rice. Unfortunately, the grain has not earned the popularity it should, considering the varied uses to which it can be put. This may be attributed to the ignorance of the growers.

b) Absence of markets.

It is not easy to induce the average farmer to make changes in his customary ways, and he will generally not plant a new crop for which there may not be a sure market and the prospect of a good price. Whether or not the mills would buy the grain would be found only after harvest.

c) Changes to be made in flour mills.

Mills cannot use all their present machinery in making flour out of adlay without first making adaptations in it and installing some new machinery. This will be done only if adlay is grown on a big scale to guarantee a steady supply and after a demand has been created for the new flour.

d) Competitive crops.

Known edible varieties, such as those described by Wester, Watt and Vallaes for Asia, grow well only in tropical countries, where other cereals are also available, and they have therefore been planted extensively only in time of scarcity.

e) Damage of crop by birds.

Pierris states that adlay is remarkably free from diseases, "but considerable loss is caused by depredations of rats and parrots". It was observed by the present writer in Brazil that if seed is not harvested before the birds discover them, almost nothing is left from a small plot. Probably this single fact has been the chief reason why adlay has not been

successfully introduced into the State of São Paulo. The trial plots there were small, and therefore the damage caused by birds discouraged experiments on a larger scale. Many other cereals suffer losses from birds, but, since they are planted on a larger area, damage to them is less noticeable.

f) Long growing season.

The long growing season has already been mentioned by Wester as one of the drawbacks of this cereal.

g) Limited keeping qualities.

The keeping qualities of the whole grain are very good, but hulled grain, if not stored in a dry place, is subject to deterioration. Rice in this respect is superior.

h) Few plant-breeding experiments.

There are many edible varieties of adlay, differing in height, yield, growing season and protein content, but up to a few years ago, systematic plant-breeding experiments had not been carried out. The seed used in Brazil since 1939 has consisted of at least four varieties, and, as they were grown together, hybridization followed. According to Wester (45), " In the branching of the straws and in the construction of the panicle as affecting the productiveness the individual plants display remarkable diversity, some yielding at least four to five times as much grain as other plants. There exists a great opportunity for improvement by the plant breeders ".

i) Uneven yield.

Due to the lack of proper selection and other factors the yields differ widely. Experiments in Buitenzorg, Java, and Fort de Kok, Sumatra, about 1922 gave yields of 2867 kg. and 3528 kg., respectively, on one hectar (7). Other reports gave much lower yields.

j) Use of farm machinery limited.

Because of diversity in height and uneven ripening, use of machinery for harvesting is limited. It can also be doubted that harvesters for other cereals could be used for cutting and threshing the tall growing adlay, with unevenly distributed seed, without substantial changes in their construction. So far, harvesting has been done by hand, the same as with rice, and threshing over a horizontal log in a rather primitive way. While this procedure is satisfactory for small experimental plantations, or where labor is cheap, it would offer a serious obstacle to production of this cereal on a large scale.

It is not surprising, in view of the foregoing disadvantages, that adlay, in spite of its many excellent qualities, has not yet become of economic importance. Some of these shortcomings have been overcome in a recently developed variety which holds great promise for future development, and it is to this variety that we now turn our attention.

The Promising Variety

In 1921 Wester expressed the following opinion in concluding his article (46): " It would appear, then, that with lower production cost and a larger yield of a better grain per unit area, adlay is destined to supplant rice as the leading staple grain not only in the Philippines, but possibly throughout a very large part of the Tropics ". This prediction, made 30 years ago, may come true through the discovery of a variety which has been grown the last few years in Brazil with very promising results. It is referred to as " dwarf variety ", " low growing variety " (porte pequeno) or as the variety with brown elongated seed.

History. In 1922 a few seeds of the tall growing varieties were sent by Wester from the Philippines to a well-known farm review in Brazil, Chacaras e Quintais, which subsequently published an article based on information given by Wester (8), and distributed seed. This initial effort to introduce adlay into Brazil failed.

In 1939 Ubirajara Perreira Barreto, agronomical engineer of the Ministry of Agriculture in Brazil, also tried to introduce the cereal. He had received seed from a colleague in Bolivia and he wrote several articles and two booklets about the great possibilities of this cereal. He also distributed seed to farmers. From him the writer received some seed, a few of which differed from the rest in being dark brown and elongated, and which Ubirajara believed to be a form of adlay, having received them from a Japanese farmer. The writer sowed them on land of low fertility. Six plants developed slowly. When other varieties of adlay, sown at the same time, had reached a height of about two meters, the six plants had grown to about 30 centimeters. After five months, when the tall varieties were flowering, the small plants carried a surprisingly great amount of ripe seed.

An agronomist, Antonio Carlos Pestana, visited the plantation of the tall growing adlay and saw the six small plants. He published an article (25), commenting on the astonishing fact that he had seen a variety of *Coix* from which he collected seed only five centimeters above the ground which differed from those of the tall growing species by being dark. He thought it to be a very noteworthy exception and referred to the seed, which he later multiplied in his garden and distributed, as seed from the "dwarf variety". This name is still in use, though the seed, planted in fertile soil, produces plants about one meter tall.

Seed collected the next year was sent to various experiment stations, and since 1944 Dr. Geraldo Leme da Rocha of the Departamento de Produção Animal has been planting it on different government experiment stations. In 1950 the area for experiment and observation was increased to 40 hectars.

After two articles were published in May and July, 1948 (31, 32), giving a description of the many advantages of the variety with brown elongated seed in comparison with the other tall growing varieties, many requests for seed were received. To all interested persons, two pounds of seed were sent free of charge in 1948 by the writer.

In 1949 the department for seed distribution of the Secretaria de Agricultura in São Paulo distributed eight 30-kilo bags to farmers, giving to each only about a kilo of seed for multiplication. The Departamento de Produção Animal also distributed seed in small bags, and over 1000 farmers have received adlay for experimenting. In 1950 the Secretaria de Agricultura alone sold 279 bags, and seed was also sold by seed stores and associations. Besides, many farmers had their own seed from their first limited experiments.

Superior Features. The surprisingly rapid response of Brazilian farmers to this variety is due to the following advantages:

a) Uniform Seed. The seed is very uniform in appearance; all plants on the same type of soil grow to an even height.

b) High Yield. The yield is higher than that of rice, and in many instances greater than that of corn. About 2500 kg. of grain has been the average harvest from one hectar. In fertile soil the yield has been 3000 kg. and higher. On experimental plots the yield has been over 4000 kg.

c) Not Attacked by Birds. The many stalks developed by one seed are thin and pliable, not giving support to birds which attack the other varieties. No serious damage by birds has so far been observed.

d) Shorter Growing Season. The growing season is about the same as for corn. In five months or less, depending on climatic conditions, the grain is ripe for harvesting. A report from Angola, Africa, stated that the seed was ripe after only three months. It can be successfully

grown in the southern States of Santa Catarina and Rio Grande do Sul, where seed of the other varieties do not ripen well.

Besides these advantages of the new variety over the tall growing adlay, other circumstances have helped in its rapid introduction in the State of São Paulo:

a) Shortage of Animal Feed. In 1948, because of certain circumstances, Brazil imported wheat flour instead of wheat, and a serious shortage in by-products of the milling industry developed, since milling operations were curtailed. Wheat bran and middlings, on which farmers greatly depend for feeding poultry and cattle, consequently became unavailable, and this situation also drew attention to dwarf adlay as a substitute.

b) Analyses and Feeding Experiments. In the search for substitutes, analyses of adlay showed its potential use for animal feed. The whole grain contains (23) 13.6% protein, 6.1% ether extract, 8.4% fiber, 58.5% N-free extract, 2.6% minerals.

Experiments (28) at the poultry experiment station of the Department of Animal Production in São Paulo proved that whole adlay grain, disintegrated in a hammer mill, can be a satisfactory substitute for wheat bran and middlings in a balanced ration for chickens. Of two lots of 45 New Hampshire baby chicks, one received a standard balanced ration with 35% of wheat bran and middlings; the other received the same ration, but the wheat by-products were entirely replaced by ground adlay grain. During the experiment data were recorded on weekly consumption of ration, general feathering condition (tail appearing and length of primaries at the 14th day, back feathering at the 8th and 14th week) and body measurements at the 14th week. The initial laying period was controlled in trap nests, and data were recorded also on average sexual maturity in days and on the number of eggs in 54 days. The following conclusions were stated:

a) Adlay was a satisfactory complete substitute for wheat bran when such bran constituted 35% of the ration.

b) At the 14th week greater increase in weight was observed in poultry fed with adlay ration.

c) During the entire experimental period a minor consumption of adlay ration corresponded to an increase in weight.

d) Until the 14th week a consumption of 5.39 grs. of standard ration and 4.64 grs. of adlay ration corresponded to an increase in weight of one gram.

e) Feathering characteristics in both lots showed no difference.

f) Noticeable difference was not presented in body measurements.

g) Body growth in pullets from the 14th to the 30th week (7th month) corresponded to minor consumption of adlay.

h) Sexual maturity in days was the same for both lots.

i) The average egg production in 54 days of control was superior in the adlay lot, with 13.30 percent higher intensity of laying.

j) For each egg produced the feed consumption was less in the adlay lot than in the control.

k) From results obtained, the adlay cereal ground may be largely employed in balanced poultry ration.

Preliminary experiments in feeding hogs also gave good results. Animals also eat the grain without being ground, which is an advantage for the small farmer.

Seed Distribution. The good results obtained in feeding experiments induced other governmental agencies to distribute seed and help to make the new cereal known. Distribution of seed is well organized in a special department, and

there are many supervised farms which furnish different kinds of seed to the government. In 1949 the first two cooperative farms for the supply of adlay seed were formed, and in 1950 the area of cooperative farms was increased to 18 hectars.

Because of the aforementioned advantages of the adlay variety with brown elongated seed over tall growing varieties and due to other favorable circumstances, progress in the growing of adlay in Brazil has been greater in the last three years than in the previous 28 years after its first introduction.

Agricultural Aspects

In addition to its distinct advantages, the new variety of adlay differs also in many other respects from varieties described by other authors. Many studies on it are as yet incomplete, and a full account of all its requirements regarding climate, soil and maximum altitude can not be given. So far, however, the following may be reported:

Climate. The variety can be grown not only in the tropics and subtropics but also in the temperate zone. It has grown well in the southern part of Brazil, in Sta. Catarina and Rio Grande do Sul, at an elevation of 800 meters, and an early frost has not been known to damage the crop. This observation has been of great importance, as it shows the possibility of adlay becoming established in temperate climates.

The necessary amount of rainfall for this variety has not yet been determined. It has grown well in an excessively wet summer, but in an extremely dry summer many grains were hollow. It apparently needs abundant rainfall after sowing and while the seed is forming.

Soil. The dwarf variety has grown well on different kinds of soil. In a dry summer it grew better on fresh soil, and on sandy soil with poor moisture-retaining quality it formed hollow seed. In soil of low fertility only one to three stalks developed from one seed, and the plants did not grow above 30 centimeters in height. Nevertheless seed was produced. In fertile soil more than 50 stalks form from any one seed, and the plants grow up to one meter in height. It seems that this variety can be grown on all types of soil where corn or other cereals can be grown.

Planting. The soil is prepared the same as for other cereals, and the time for sowing is the same as for corn. Sowing is by machine in rows, 60 cm. to one meter apart, depending on the fertility of the soil. It is important to keep the weeds under control during the first month. Experiments conducted by Dr. Glauco Pinto Viègas on time of sowing, width between rows, density of seed, depth of sowing, according to private communication, have shown that:

a) The time of sowing appears to have a determining influence on the growing season and yield. Seed sown at the Instituto Agronomico in Campinas, Brazil, on October 1, 1949, flowered after 63 days and was harvested after 138 days, yielding 4568 kg. per hectar. Seed sown on January 1, 1950, flowered after 81 days and was harvested 126 days after germinating, yielding 1502 kg./ha.

b) The best distance between rows is 60 to 80 centimeters. Greater width diminished the yield per hectar.

c) The amount of seed per meter of row was 3.8 grams, corresponding to about 70 seeds. Double or fourfold this amount did not have significant influence on the yield. In rows 60 cm. apart, 14 kg. of seed was used per hectar; in rows 80 cm. apart, ten kg.

d) A seedling depth of about five centimeters is best; a depth of 15 cm. gave poor results.

e) The experiments with different kinds of fertilizers gave no statistically significant result and will have to be repeated.

Harvesting. In Brazil most harvesting is done by hand, and is the same as for rice. This method would not be satisfactory for big plantations. It is possible that combines can be used in the same way as for harvesting barley. Only if adlay can be harvested by existing machines will it be possible to grow it on as large a scale as other cereals. It has the advantage over rice that sowing and harvesting can be done mechanically.

Enemies. Most authors report that adlay is free from disease, and so far in Brazil no serious disease has been observed. The writer did, however, discover a few plants attacked by a fungus which was identified in May, 1948, by the Instituto Biologico in São Paulo as belonging to the genus *Helminthosporium*. The disease was similar to footrot in wheat. As a safety measure all seed distributed by the writer in 1948 was disinfected with Arasan. In subsequent years no further attack has been reported. In Trinidad, however, a demonstration plot of adlay sown in 1941 was severely attacked by the fungus *Colletotrichum graminicolum,* causing abundant, small, red-brown lesions on young and old leaves.

Need for Experimental Work

Many questions about adlay cannot yet be fully answered. Feeding experiments with chicks and hogs, for instance, at the Departamento de Produção Animal in São Paulo seem to confirm the references of Wester and other authors to adlay's high biological value (46), but there is disagreement on this point from other sources. Furthermore, the amino acids of adlay have not yet been fully determined. The protein content varies for reasons not yet explained.

Plant-breeding experiments and genetical work are still in their beginning. Through systematic selection, improvement of the grain should be achieved. In the first years of experimentation the writer selected the seed of early maturing plants with good yield, and used these for multiplication. But as adlay is easily cross-pollinated, more work should be undertaken. Plants with desirable characteristics can be propagated by dividing their roots, and the writer obtained 20 new plants from one original seed. Colchicine treatments were made in 1943 and produced a thickening of the shoots. The plants thus treated grew well but were lost by accident before determinations could be made. The number of chromosomes in *Coix* is $2n = 20$ (41).

Kempton observed that " like in maize, cross pollination is the rule and it is not surprising therefore, that with soft and hard shell forms growing side by side, few true breeding types are found. That interbreeding is the explanation of the change from hard to soft shells under continued cultivation is indicated by the hard-shelled strain of *Coix Lacryma-Jobi* which has been cultivated for centuries in Europe and America without losing to a noticeable degree the hardness of the shell ".

" *Coix* should appeal to the geneticist, since the variability in seed and plant characters is great and the genus presents interesting morphological features ".

After an article about adlay was published in Spanish (33) and in Portuguese (34), seed was sent from Brazil, in response to requests for it, to Angola, Colombia, Mexico, Costa Rica, El Salvador, Honduras, Nicaragua, Uruguay, Chile, Peru, Honolulu, Italy, Germany, United States, Mozambique and Belgian Congo.

In the United States experiments are being made by the University of California, University of Miami and by the Division of Plant Introduction and Exploration in Beltsville, Maryland. In Africa adlay has been successfully grown in Angola; in Nicaragua it gave a good

yield and tillered well; and in Italy it produced ripe seed in Florence.

Conclusions

Experiments in Brazil have demonstrated that the dwarf variety of adlay with brown elongated seed can grow successfully in different States of that country. Through private and governmental initiative remarkable progress in its culture has been made within a few years. It is probable that adlay will be grown each year on a larger scale and that at some time in the future it will become of economic importance.

It is now too early to draw conclusions about the possibilities in other countries. An initial interest has been aroused, but so far most experiments are being made by private farmers. If the first experiments should fail, due to circumstances which may have no bearing on the possibility of growing adlay in those countries, further attempts will probably not be undertaken. Progress may be achieved, however, if interest for study and experimentation can be awakened in plant breeders, geneticists and agronomists.

Summary

Coix Lacryma-Jobi, commonly known as " Job's tears ", has been known in Asia for thousands of years, and its bead-like seeds have long been used for ornamental purposes, and ground into flour. In 1920 P. J. Wester proposed the name " adlay " for the edible soft hulled varieties which have been cultivated for food since ancient times in different Asiatic countries. As the grain posesses many excellent qualities, he expected adlay to become an important food for tropical countries, substituting for rice.

A new variety of adlay, with brown elongated seed, has been grown successfully in many States of Brazil. Over other varieties it has the advantages of more uniform seed, higher yield, freedom from attack by birds, shorter growing season and high protein content. The grain can be used in different ways for human consumption and animal feed, and the leaves make good fodder, silage or compost. It probably can be used also for the manufacture of starch and flour. It can be used on the farm where it is grown, thus facilitating its initial introduction, and it grows in the tropics, subtropics and temperate zones. Experiments are being conducted in many countries.

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Utilization Abstract

Diatoms. These microscopic unicellular forms of plant life, which live to the extent of millions in nearly every cubic foot of salt and fresh water, form many thousands of square miles of sediments in various parts of the world where their siliceous remains have accumulated throughout the ages. These accumulations are known as " diatomaceous earth ", and hundreds of thousands of tons of this uniquely resistant and porous material are annually used in industry for high-temperature insulation, filtration of many commercial products, polishes, fillers, absorbents and a great variety of other uses. The principal source of the material in the United States is the deposit of the Johns-Mansville Corporation at Lompoc, California.

More important to mankind as a whole than this direct industrial utilization, is the fact that the diatoms of the sea are by far the most important form of plant life converting the dissolved substances of the ocean, along with photosynthetic organic substances which they manufacture, into the food that constitutes the basic sustenance for all animal life of the oceans, a function which they share, but only to a small degree, with flagellates and some other forms of microscopic floating plant life. Vitamins A and D, so abundantly supplied by the liver oils of various fish, especially cod, halibut and shark, are not manufactured by those animals but only accumulated by them from the diatoms which they consume. This great biological fact induced the Dow Chemical Company during World War II to attempt extracting the oil directly from diatoms. " The attempt at their plant in North Carolina, where they so successfully extract bromine from sea water, did not prove feasible, however, because the sheer mechanical difficulty of straining oily, gelatinous objects like diatoms, in mass, from vast quantities of sea water was not as simple as the precipitation of a chemical element. On the other hand, fish, not fixed in any one place like a chemical plant, but free to swim continually in search of areas where at the moment diatom growth might be heavy, and possessed of a delicate gill-raker mechanism for separating the solid plant food from the water, could do the job infinitely better; hence it was left to them ".

A third significant role of diatoms in the economy of the world is the great likelihood that they were responsible for all petroleum. Whether petroleum originated directly from diatoms and other plant life of former seas or from the decay of marine fish and other animal life, in the last analysis it was photosynthetic activity of plant life that produced the oil.

A fourth service of diatoms is that of aerating the water in which they live, a role that may be significant in quiet or ice-covered waters where other means of aeration for the benefit of animal life are lacking.

Transcending all these functions, however, is what may be regarded as the most important of all, namely, that by being concentrated in the mouths of rivers and in coastal waters of the world, diatoms intercept all dissolved materials and thus " constitute an effective biological barricade against loss of these valuable materials to the vast spaces of the open oceans ". (P. S. Conger, *Sci. Mon. 73: 315. 1951*).

Grapefruit and Pummelo

Grapefruit is of American origin, possibly a natural hybrid between pummelo and orange of the Old World. The United States produces more than 90 percent of the world production in excess of 50 million boxes, and more than half of the American crop is now marketed in processed form.

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Botany

In considering the production and utilization of these allied fruits, their botanical relationship calls for first consideration. Formerly regarded as varieties of a single species (*Citrus grandis* Osbeck), they are now recognized as constituting two distinct species. The name *Citrus grandis* is retained for the oriental pummelo group, often called " shaddock " in the western world. The name " shaddock " is derived from the fact that a certain Captain Shaddock is reputed to have brought seed from the East to the West Indies, first planted in Barbados late in the 17th century. Grapefruit, as we know it, differs in such important characters that it is now accorded the specific name *Citrus paradisi* Macf., first so recognized by Macfadyen (14) in 1830 but not generally accepted until in recent years.

One fundamental difference between grapefruit and pummelo is the fact that the latter fruits are unique among citrus species in having seeds with but a single embryo, while grapefruit seeds are polyembryonic. The extra embryos in the latter case are derived from the nucellus or mother tissue of the seed and give rise to seedlings that usually dominate the sprout from the true or seminal embryo and thus reproduce the parental characters practically unchanged. This fundamental difference between the seed of the two species lends confirmation to the belief that the grapefruit originated as a hybrid between the pummelo and the orange (*Citrus sinensis* Osbeck), the polyembryonic character of the orange being dominant. A further indication of the pummelo's functioning as one parent is the occasional occurrence of pink-fleshed grapefruits (16), these appearing as single branch mutations of standard white-fleshed varieties. This may be interpreted as a throw-back to a pink-fleshed parent, a character frequently found among the numerous varieties of pummelo. Just what set of factors leads to the rare but occasional expression of this latent character is impossible to analyze. These pink-fleshed grapefruit varieties will be referred to later. Chemical evidence linking grapefruit with the pummelo is the fact that they both contain the same glucoside, naringen (28), differing from the glucosides occurring in other citrus fruits. The pummelo and grapefruit, in common with all true citrus species, have the haploid chromosome number nine (30).

Besides the botanical difference involving the seed, there are other outstanding botanical differences between the pummelo and grapefruit. As Swingle (28) points out, *Citrus grandis* is an easily recognized species despite the nu-

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merous local varieties—variations involving size, color of flesh, thickness of rind, seed content, sweetness or acidity, as well as foliage and growth habit. Its thick, often pubescent, angular young twigs, with huge leaves borne on broadly winged petioles and its very large flowers, make the species impossible to mistake. The segments are split open at the center toward the open core, segments separating easily, segment membranes thin but tough and readily removed, leaving the mass of pulp vesicles intact.

Fig. 1. Typical view of young grapefruit grove spreading over the sandhills of central Florida.

History

Grapefruit was first mentioned by Griffith Hughes in 1850 (12) under the name " forbidden fruit " as occurring in Barbados and is recorded from Jamaica as " forbidden fruit or smaller shaddock " by Patrick Browne in 1789. Descriptions make it clear that the fruit in question was not a pummelo or shaddock but an improvement on the latter. In 1814 John Lunan (13) first used the name " grapefruit " in his Hortus Jamaicensis, " on account ", he says " of its resemblance in flavor to the grape ". This statement negates a current idea that the name was applied because the fruit sometimes occurs in huge grapelike clusters. Horticulturists have tried to have the name " pomelo " substituted for grapefruit but without success.

A further reason for regarding grapefruit as of American origin is the fact that extensive explorations in southeastern Asia and Malaysia have failed to disclose the existence of any citrus fruit even closely resembling grapefruit, though numerous strains and varieties of the pummelo are widely distributed in that part of the world.

The merits of the new fruit were apparently appreciated by a select few in

the West Indies, but it failed to meet popular approval for a surprisingly long time, its real economic expansion occurring in Florida. Introduced into Florida in 1823 by Count Odette Philippe (18), a French nobleman who located near Safety Harbor on Old Tampa Bay, it spread slowly but was grown chiefly as a curiosity or for home use. The Count distributed seed and seedlings to neighbors and friends in the Tampa Bay region, and one of the seedlings thus originating proved to be the parent tree of the grapefruit variety in Florida that for many years was the leader and standard of excellence, viz., the Duncan grapefruit (31). Count Philippe brought trees of bearing age and size from the Bahamas for his Florida planting. His presence in the Bahamas was due to his being sent there by the British as a prisoner of war following the great naval battle of Trafalgar. He was Chief Surgeon of the French Navy under Napoleon, and his services in the Bahamas as a physician were so greatly appreciated by the British that after a few years he was given his freedom. Captured by pirates, he cured the sick members of the crew and was again released and furnished a map of the Tampa Bay region with a glowing account of its advantages, an event that meant much to Florida's later development. It was not, however, until winter visitors from the North developed a liking for grapefruit that any trade in it was established. This happened between 1880 and 1885, the first shipments north being made in barrels that netted about fifty cents a barrel. Only with the coming of the present century, however, did grapefruit really begin to command a place in the fruit markets of the nation. Once started, the demand increased at a rate unparalleled by that of any other newly introduced fruit.

The pummelo, or shaddock, has received so little attention as a commercial product in the western world that there is little on record as to its history in America or its utilization. In the Orient, however, its merits have been appreciated for centuries, and it has not been displaced to any extent by the more modern grapefruit. As a matter of fact, the rather solid flesh of the better varieties of pummelo render the fruit more suited for use as a salad than as a breakfast fruit, for which grapefruit is chiefly adapted. Thus they are not rivals to any extent.

Varieties

Grapefruit. No discussion of a fruit industry can be comprehensive without an understanding of the chief characteristics of the main varieties. The Duncan variety, already referred to, is often listed as early maturing and is recognized as a standard of excellence. It has, however, a long season, shipments often extending from October to April, after which numerous seeds begin to germinate, lowering the fruit quality. The Walters variety, generally rated as "midseason", does not materially differ from the Duncan. As a matter of fact, the main commercial varieties, besides those mentioned, as Hall (Silver Cluster), Excelsior and Connor, are so similar that it is probable that they originated as nucellar seedlings from a few trees of early introduction into Florida, their differences hardly warranting variety classification. A budsport of the Walters, the Foster (16) (Fig. 2), discovered in the Atwood grove near Bradenton, is pink-fleshed and was the first pink-fleshed variety to be commercially planted. Another group of smaller rounded fruits, as the Triumph, Royal and Leonardy varieties, are distinct, but they have been practically abandoned as commercial varieties.

In the field of late varieties there is, however, an outstanding one, the Marsh, unique for its seedless or near seedless

FIG. 2. Original tree of Foster grapefruit, showing mutating branch, marked "pink," which produced the pink-fleshed fruit; balance of tree producing white-fleshed fruit typical of the Walters variety. (*By permission of Journal of Heredity*).

character. This variety, although known and propagated since 1895, did not attain outstanding popularity until about 30 years later. The original tree was a seedling growing in the Hancock grove near Socrum (17) about 12 miles north of Lakeland, Florida. During recent decades it has predominated in practically all new grapefruit plantings. This is especially true in Texas, Arizona and California as well as in foreign fields.

A pink-fleshed bud sport of the Marsh, the Thompson (16), originating like the Foster near Bradenton, Florida, has come into great popularity and constitutes a large part of all new plantings.

With the development of a large scale canning industry, it has been found that the seedless fruits are not well adapted, the segments often disintegrating in the can. It is unlikely therefore that the seedy varieties will be abandoned. The juice of the pink-fleshed fruits also loses its color in the process of canning. The freezing process may, however, overcome the difficulty experienced with disintegration of segments and loss of color in preserved juice. There is one seedless variety, the Davis, at present little planted, that can be used in canning without the difficulty of segment disintegration experienced with Marsh.

The Davis variety originated, as pointed out by Traub and Robinson (30), in the process of hybridization, the original seedling (not a hybrid) arising from the application of tangerine pollen to grapefruit bloom with the object of producing a hybrid known as the " tangelo ". The grapefruit has served as the seed parent of a whole new class of citrus fruits, the tangelos, which are rapidly finding a place on the American market. These hybrids of the tangerine and grapefruit resemble neither parent very closely, being more in the nature of a super orange but with the color and zest of the tangerine. Although derived from the grapefruit as the female or seed parent, these newly created fruits are destined to compete chiefly with the orange.

Pummelo. Although a score or more of the best varieties of pummelo have been introduced by the U. S. Department of Agriculture and tried out in the United States, they have never attracted favorable attention as commercial prospects. People who have lived or traveled in the Orient acquire a liking for the fruit, and a private trade might be developed with a limited clientele already familiar with the fruit and how to serve it, but it is not likely ever to rival the other citrus varieties with which we are familiar. The writer once made a canning test of the segments of pummelo, the results of which were decidedly favorable, but it is unlikely that a planting solely for this purpose would be worthwhile. In the Orient, where there is already a large production, an enterprise of this sort might pay, even if carried on only for export.

Among the varieties that offered promise in trials made in Florida may be mentioned the Kao Panne, Kao Phuang, Nakorn Chaisei, Thong Dee, Lau Chang, Java, Siam and Indian Red. As a rule, the pummelos require a warmer climate to thrive than the orange or grapefruit.

As pointed out by Groff (9), the pummelo is usually propagated in the Orient by marcottage, or Chinese air layering, an ancient form of propagation. It is a slow and laborious method and doubtless operates to restrict plantings to comparatively small areas. The pummelo, with its very thick rind, can be shipped long distances with little loss, so that the fruit is available in coastal cities of China far removed from the citrus growing areas.

Soils

For production purposes the grapefruit is fairly tolerant of soil character

and reaction. While grown with success in tropical regions, it attains its best quality in subtropical areas fairly free from killing frosts or at least severe freezes. Regions experiencing a fairly high humidity are more favorable to grapefruit culture than arid or semi-arid areas. In Florida the area of greatest production is south of the center, orange culture extending considerably farther north. In Texas and the Southwest only the warmer valleys permit grapefruit growing and then with some hazard.

The sandhill region of Florida's central ridge produces about three-quarters of the State's total crop. In this region the soil reaction is usually mildly acid, sometimes benefitting from application of lime. Some East Coast soils underlaid with coquina shell deposits or with marl and the extreme southeast oolitic limestone areas are, on the other hand, alkaline but not to an injurious degree. The soils devoted to grapefruit in south Texas, California and Arizona are predominantly alkaline. With the need for rather frequent irrigation in these areas, there is a tendency for an accumulation of alkaline salts to a harmful degree.

Rootstocks

The soil, as to its fertility, drainage and reaction, has a determining effect on choice of rootstock. In the porous sandhill soils of interior Florida the Rough lemon rootstock has proved best adapted, though there are growing indications that trees on this stock are not destined to be long-lived. A similar decline of citrus on this rootstock was observed in South Africa (19). For the heavier hammock and flatwood soils along the coast the sour (or Seville) orange has long been the preferred rootstock. A compromise for medium grade soils, fairly well drained, has been found in the Cleopatra mandarin, but this stock has not proved well adapted to grapefruit.

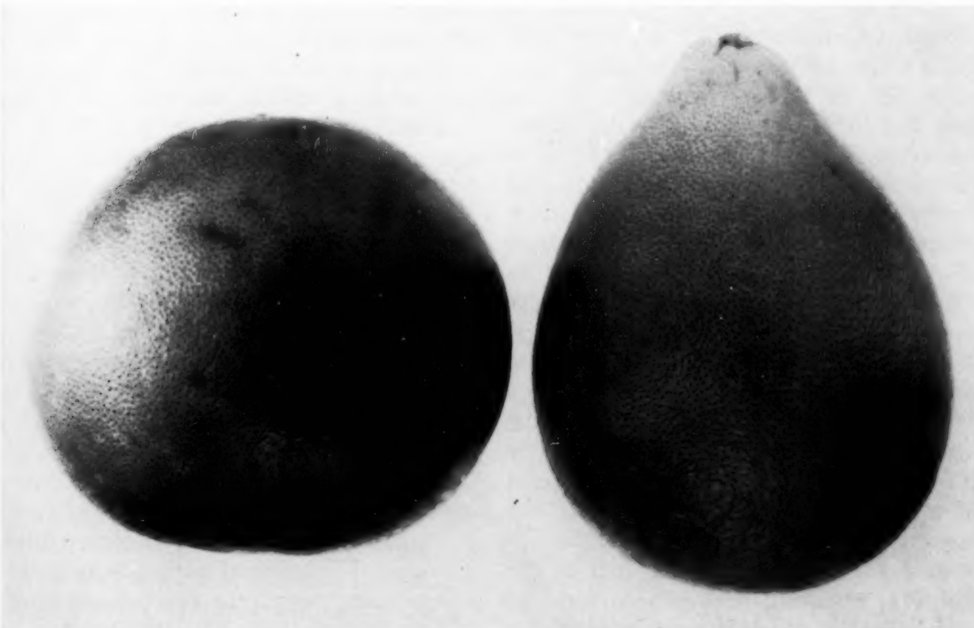

FIG. 3. Two types of pummelo, Siam (left) and Thong Dee (right); half natural size.

In the Rio Grande Valley of Texas

soil conditions seem best suited to a single rootstock, the sour orange. Likewise in Arizona and California the sour orange has long been the preferred stock. In California of late there has been a considerable switch to the sweet orange as a rootstock because of the threat of a virus disease, quick decline, that in a few years kills trees, both orange and grapefruit, budded on the sour orange rootstock.

Production

Soil Amendments. Production and quality are influenced by so many factors, such as cultural methods, sanitation and fertilization, that no one factor can be held as determinative. An example of this that has come to the fore in recent years is the inclusion in fertilizers or sprays of the so-called supplementary plant foods or micro-elements besides the traditional nitrogen, phosphorus and potassium. These elements include copper, manganese, zinc, iron and boron in small amounts, often most effectively supplied in the form of a spray. A major need in some Florida areas, particularly for the seeded grapefruit, is some form of magnesium. It was found that the numerous seed of grapefruit remove excessive amounts of magnesium from the soil (7), resulting in a severe form of leaf bronzing which is readily corrected by magnesium applications. Attention to such needs has resulted in largely increasing yields and in improving fruit quality. Improvement in the general health of the tree has been noted as increasing the tree's resistance to cold injury, a factor in maintaining good production.

In south Texas less attention needs to be paid to fertilization or supplementary plant foods, but poor drainage in some areas, with consequent water logging of soils and accumulation of excess salts, tends to lower production and is a threat to a stable industry. With improved methods of irrigation and drainage, this factor is gradually being overcome. In recent years a series of freezes has cut production.

In Arizona likewise grapefruit production far exceeds that of oranges and is almost wholly made up of the seedless varieties. While a good part of the crop is utilized in the far west, shipments to the eastern markets are considerable, especially after the Florida crop is out of the way.

In California grapefruit production is of minor importance compared to the orange crop, and the fruit is largely used locally and in the far western cities, shipments east being largely confined to the summer months. No attention has been paid to the culture of the pummelo in these western States. In California, with its sprinkling of Orientals, the few pummelos grown, usually as dooryard trees, find a ready sale at very good prices. But for the need to maintain quarantine restrictions against imported citrus fruit, there would probably be a considerable importation of pummelos by Orientals.

Sanitation. Protection against insect and fungus pests, while not always rated as a major production problem, could, however, if neglected seriously threaten a continued supply of marketable fruit. Twice Florida had had to carry on a war of extermination against threats of this kind—first against a bacterial disease, citrus canker (1914–1918), especially severe on grapefruit; and more recently against the Mediterranean fruit fly (1929–1932), likewise a major pest of grapefruit. Fortunately these campaigns were conspicuous successes, affording an unparalleled record of accomplishment in the seemingly hopeless task of complete eradication. Success in each case called for heavy expense, much loss of fruit and personal sacrifice on the part of many growers. Other foreign pests are known to be equally dangerous,

and eternal vigilance is required to insure a continuing supply of fruit to meet the growing demand.

Statistics [2]

Reference has already been made to the rapid increase in grapefruit consumption once the American public became familiar with the merits of the fruit. To appreciate this phenomenon, some statistics (26) are impressive and revealing. Taking Florida only, the first years for which there are statistics were 1889 and 1899, when the production was 10 and 12 thousand boxes, respectively. Within ten years (1909) the production had reached a million boxes. The average annual production for the succeeding periods of ten years each (1919–1928, 1929–1938, and 1939–1948), expressed in round numbers is as follows: eight million; nine million; and for the last ten years, 24 million boxes. When Texas production is added to these totals, the results are really startling. Starting much later with one and one-half million boxes in 1929, the average annual production for successive ten-year periods (1929–1938 and 1939–1948) is five and 18 million boxes, respectively. In 1949 the production dropped to six and one-half million, due to a freeze the previous season. With the combined grapefruit production of Arizona and California reaching five to seven million boxes annually, it will be seen that the consuming public has greatly increased its capacity to absorb this vast amount of grapefruit. Part of this enormous increase is of course due to the development of processing procedures which will receive attention in a later chapter. Instead of being a seasonal crop, grapefruit has become available throughout the entire year, either in fresh or processed form.

[2] Since the following statistical material was prepared, production figures for the 1949–50 season have become available. These figures do not materially alter the picture except that the trend toward greater utilization of grapefruit in processed form was accentuated, particularly as a frozen product. The prevailing high prices for the 1949–50 season compensated to a marked degree for the disastrous seasons experienced from 1946 to 1948.

Production Areas

As to the world production of grapefruit, the United States produces about 90 percent of the world supply of grapefruit each season (6). The other producing sections of North America are Cuba (including Isle of Pines), Jamaica, Puerto Rico, Trinidad and Tobago. These West Indian islands grouped together rank second in importance in the world grapefruit picture, producing about three and one-half percent of the total in 1950. Third in importance is the total production of Cyprus, Palestine, Africa (19) and the Philippines. The United States alone in 1950 produced $47\frac{1}{2}$ million out of a world total of $51\frac{1}{2}$ million boxes of grapefruit, or 92 percent. In contrast with the great preponderance of the United States in production of grapefruit, it may be pointed out that the United States produces slightly more than one-third of the world supply of oranges—110 million boxes, as against a world production of 291 million in 1950.

Processing

Reference has already been made to the effect on grapefruit production brought about by the development of various preserving processes. The canning of grapefruit sections or "hearts" had its inception at the time of the first World War. For lack of shipping, growers in Puerto Rico were unable to ship their crop, so decided to try salvaging at least a portion of the crop by canning. The result was an encouraging success and the practice was soon taken up in Florida and later in Texas. At first the canning process was regarded as a means of salvaging fruit of off grade

but sound—fruit that either went into the cull pile or, if shipped, had a depressing effect on the market generally. The reception of the product by the public soon demonstrated, however, that canned grapefruit was destined to play a much more important role than that of salvage, and the product became a standard article of trade. The canned product not only extended the marketing season but made it possible to put grapefruit into stores of the smaller towns that seldom handled the fresh fruit. Such fresh fruit as reached these numerous small towns came after reshipment from the carlot markets. This usually made the fruit so expensive that it was mainly a luxury fruit, a situation that greatly restricted consumption. Transportation by motor truck has remedied this situation to quite an extent, but there are still many smaller communities where fresh grapefruit is a rarity. The truck movement in 1949–50 from Florida amounted to 6,315 carloads of grapefruit as compared with 9,437 carloads shipped by rail and boat, both based on a load of 500 boxes per car (32).

Another factor favoring the canned product is the ease of service. The preparing of grapefruit for the table when there is a large number to be served, as in the restaurant trade, is a time-consuming job. The canned fruit soon became popular with this class of trade, and special large containers were put up to cater to this demand. Thus grapefruit not only became a favorite breakfast fruit but was soon in demand for use in salads and desserts, competing strongly with preserved pineapples, pears, peaches and similar fruits.

As the consuming public became more and more vitamin conscious, the demand for grapefruit, in both sections and juice form, was speeded up. Blending of grapefruit and orange juice also became popular, the combination suiting some tastes better than either fruit juice preserved separately.

The outstanding value of citrus fruits, especially as a source of vitamin C, played a large part in the rapid expansion of the preserved juice industry, especially during World War II. Recognition of the importance of an adequate supply of these vitamins led the dieticians of the U. S. Army to include large quantities of both orange and grapefruit juices in the soldier ration, especially in the training camps. This demand, along with the need for supplying the children of our allies, especially in England, with adequate amounts of vitamin-containing juices, became so great that nearly one-half of the entire pack of processed grapefruit during the war was required to fill government orders. The expanding school lunch program likewise has had a noticeable effect on the increasing consumption of citrus juices. A few figures (24) will give an idea of how rapid this growth was, especially during the war period.

During the year 1935–36 approximately two and one-half million cases (or equivalent of 24 No. 2 cans) of grapefruit juice were put up in the United States; by 1940–41 this figure had risen to 16¾ million cases, and in the war year 1945–46 to 26 million cases, of which Florida produced 15 million and Texas nine and one-half million. Added to this total there was a large pack of blended grapefruit and orange juice. The blended juice had first made its appearance on the market in 1935–36 in a small way, but in five years (1940–41) had risen to two and one-half million cases, and by 1945–46 had reached 13½ million cases. These war-time figures for juice packs were not maintained, though the pack of grapefruit segments was not affected to any great extent. The pack of segments for the past five years has fluctuated somewhat but has

maintained an average of nearly four million cases per annum. Likewise the pack of blended juice has been maintained at a fairly high level, with nearly 11 million cases in the 1948–49 season.

The sudden dropping off of government orders at the close of the war led to acute distress among citrus growers for about three years and was especially onerous for those mainly producing grapefruit. From the high figures of 26 million cases of grapefruit juice in 1945–46 there was a drop to 17½ million the following year and about 12 million in 1949–50. There had been a heavy carryover of processed grapefruit from the war years that was disposed of only at disastrously low prices. This led to a more conservative operation in the processing field that was gradually compensated for by the sensational appearance of two new products—processed concentrated juice and frozen concentrated juice. While these new processes applied mainly to oranges, the utilization of grapefruit was by no means inconsiderable. In the season 1947–48 the pack of processed grapefruit concentrate totaled nearly one and one-half million gallons. At that time only a beginning had been made with the frozen concentrate. Two years later (1949–50) conditions were reversed with one and one-half million gallons of frozen grapefruit concentrate and only 28 thousand gallons of the processed juice concentrate. In this latter year there was also a pack of one and one-third million gallons of frozen concentrate blend juice. A gallon of juice represents roughly about a box of fruit consumed; somewhat less for the frozen product and somewhat more for the processed concentrate.

Crop Values

How greatly crop values may be affected by the amount and value of grapefruit used in processing may be seen from the on-the-tree price received for fruit (26). While this price for the United States during the war years (1943–1946) averaged around a dollar and a half per box, the price for fruit used in processing for the three succeeding years (1946–1949) fell to 43, 13 and 43 cents, rebounding to $1.63 in 1949–50. The fresh fruit price during this period was also depressed but far less than the processing figure, averaging two to three times the latter. However, the build up of the business of merchandising citrus fruit in concentrate form, particularly the frozen concentrate, has been so spectacular that experts now feel there is slight need to fear in the future such a debacle as occurred immediately following the war years.

By-Products

So rapid was the growth and importance of citrus processing that in 1948 the Florida State Horticultural Society had to set up a special section, Processing Section, to deal with this subject. In the meeting of that year five papers were presented, and in the following year the number increased to seven. These papers dealt not only with the production of a product for human consumption, but also with utilization of the waste products. From the beginning of the canning of grapefruit, disposal of the residue has offered a problem and still does to a considerable degree. However, the research work done on producing an edible cattle food, on citrus molasses, feed yeast, oil from seed and rind, pectin, industrial alcohol and similar by-products, offers a hopeful means of solving earlier difficulties, and in some instances is turning an expense item into one of revenue production.

A few figures will give an idea of the build-up of these by-products in the processing industry (26). In the 1940–41 season there was a production of

33,000 tons of citrus feed. There has been a steady increase since then, the 1949–50 figure reaching 163,000 tons. Molasses, a new product, first appeared in the 1943–44 season when 14 tons were first produced. Since then the average output has been about 50 tons per year, and pastures with molasses tanks are becoming a common sight about the State. Some of these by-products are so new that standardization is an urgent need, and work along this line is being actively pressed by several cooperating agencies. Chief among these may be mentioned the Florida Citrus Commission, the U. S. Citrus Products Station, the Florida State Experiment Station and the Florida Canners Association.

Utilization

Some fears are expressed from time to time that the processed fruit, particularly the concentrate, may have a depressing effect on the fresh fruit market. Evidence of this has been at times contradictory, but in the case of grapefruit there does not seem to be grounds for much apprehension. The major part of the grapefruit crop that goes to the processing plant consists of fruit that, while sound, is of a grade not generally acceptable to the fresh fruit trade. Such fruit stands a better chance of showing a fair profit in the processed form than if shipped fresh. The reduction in bulk represents a great saving in freight, as much as 90 percent in the case of concentrated juice, and nearly as much with the full strength juice.

Previous to the introduction of processed grapefruit in the form of sections or juice, grapefruit served almost solely as a breakfast fruit. Its utilization has been greatly expanded in recent years, the sections finding favor in salads and desserts, the juice in cocktails or appetizers, or simply as thirst quenchers at the soft drink stands. Introduction of vending machines promises to greatly expand the latter phase of business, the public finding a special appeal in this self-serve type of merchandising. Blended grapefruit and orange juice is especially popular at the counter, grapefruit supplying the zest to the combination sometimes lacking in orange juice when low in acid content. It is here that the concentrated juice makes a special appeal to the operator of a soft drink stand. He can reconstitute the juice in a few minutes by adding the required amount of water, thus avoiding the time consuming job of extracting juice from the fresh fruit.

Citrus and Public Health

The soft drink business in the United States is of colossal proportions. Most of the bottled drinks offered and advertised extensively are devoid of real value from the standpoint of supplying vitamins or essential minerals. If the public could be won over to the general substitution of citrus juice for these synthetic soft drinks, some of which are habit-forming and expensive when considered on the basis of nutritional value, there would be a public benefit, the extent of which can scarcely be over-emphasized. This is particularly true in the case of growing children who too often become addicted to the soft drink habit and for whom adequate amounts of vitamin C and calcium are especially important. Much attention in recent years has been given by doctors and public health officials to the subject of dental decay and its prevention. It has been generally recognized that citrus fruit plays an important role in the maintenance of dental health because of its high content of vitamin C. It has also been repeatedly demonstrated that with methods generally employed in preserving grapefruit, either in sections or juice form, very little of this essential vitamin is lost. The importance of this finding in the case of growing children is apparent in

view of the available evidence that defective tooth structure originally caused by vitamin C deficiency may be responsible for serious dental disease during adult life.

As a result of the benefits resulting from the use of citrus juices in the Army ration during World War II, the armed forces are again including generous amounts of both orange and grapefruit juice in the dietary, chiefly in the concentrate form. Citrus juices have been provided not only in the training camps but also for those serving on the fighting front in Korea. For every 1000 pounds of rations, 174 pounds of citrus products are included. In addition to grapefruit juice, a considerable amount of canned grapefruit is provided. Not only has the use of citrus products been found to contribute much to the health and morale of the soldier, but recovery from wounds and shock is greatly expedited thereby.

Processing, a Major Factor

The rapid growth of grapefruit utilization in processing may be realized from a few figures. Since 1941 the amount of fruit processed in the United States has exceeded the amount disposed of as fresh fruit in every year except two. For Florida an excess of processed over fresh fruit utilization has been the rule without exception during the nine-year period, 1941–1950. For the whole period about 150 million boxes of grapefruit have gone into processed form as against 90 million sold as fresh fruit. For Texas the figures for this period are a total of 69 million boxes processed as against 89 millions sold as fresh fruit. As previously mentioned, the war years furnished a great stimulus to processing, resulting in a sharp falling off in the total pack and development of new and improved methods. In Arizona and California processing of grapefruit is of less importance, although in Arizona in some seasons as much as one-third of the whole crop has been utilized in processed form.

Economics

The warning cry of over production, particularly of grapefruit, has been sounded perennially ever since grapefruit growing began to be a major industry. Just when these warnings seemed to be well founded, usually something has happened to restore a balance between consumption and production. Sometimes it has been an act of nature, such as a freeze, cutting production for a season or two and allowing expanding consumption to catch up with production. Again it has been the opening up of new markets through advertising and sales promotion efforts. More recently introduction of processed grapefruit in its various forms and its prompt favorable reception have averted what seemed to be a real threat to the industry. Another factor, perhaps as important as any of these but apt to be overlooked, is the steadily rising per capita consumption of grapefruit, both in the fresh and processed form. This factor is especially significant when juice consumption is considered. Beginning with 1929 when this type of utilization became a factor, the per capita consumption of grapefruit juice (10) in the United States rose steadily from one-half pound to six and one-half pounds in 1946. Besides the juice pack, there was a per capita consumption of grapefruit segments since 1929 averaging nearly one pound per annum. During the latter part of this period (1936–1946), when blended juice first appeared on the market, the per capita consumption of blended grapefruit and orange juice rose from a negligible amount to nearly three pounds per annum.

The large increase in population during the last decade has tended to stabilize the per capita consumption. This is especially noticeable in the figures for

fresh fruit, no doubt affected by the expanding use of processed fruit. It can be readily appreciated what a stabilizing influence the increasing consumption of processed grapefruit exercises on the economy of grapefruit growing.

It has been stated that if the citrus growers of the United States could capture as little as five percent of the soft drink business of the country, the spectre of overproduction need never again be a worry. It would seem as though such a goal should be fairly easy of attainment in view of the recent improvements in processing, especially in the field of frozen concentrates.

Price and Supply

The effect of supply on price is usually so evident as to be taken for granted. Crop estimates are awaited annually to help determine a reasonable expectation of the growers' return. The effect of price on future supply is rarely given consideration. There appears to be a positive correlation between the prevailing price of grapefruit and production. This is illustrated by comparative prices and production in certain periods. From 1935 to 1940, a period of falling grapefruit prices, the on-the-tree price of Florida grapefruit decreased from about 75 cents per box to 35 cents. During this period production increased from about 15 million boxes to about 20 million, an increase of only 25 percent. From 1940 to 1944, a period of rising grapefruit prices, the price increased from 35 cents to $1.55 per box, the production increased to 33 million boxes, or 65 percent over the 1941 figure. On the average, grapefruit production increased 13 percent per annum during a period of rising prices but only three and one-half percent per annum during the period of falling prices. This situation can largely be accounted for by increased fertilizing, use of water, sanitation and generally improved care of groves when the crop is showing a profit.

Cost of Production

Studies available on the costs of grapefruit production (20) in Florida are usually derived from groves in which both oranges and grapefruit are planted, with the grapefruit acreage amounting to about one-third the total area. Since operating costs do not vary widely in the handling of orange and grapefruit groves, these figures may be taken as fairly accurate for grapefruit production. According to some records on limited acreage, the operating costs for grapefruit average about ten percent more than for oranges, due chiefly to the greater size of the trees. While the per-box returns on grapefruit are highly variable from one season to another, the cost per acre to produce the fruit is fairly constant over a period of years. It is true, however, that there has been a steady increase in the cost of production as between the last two decades, for example. Studies on about 200 groves for the crop years 1930–1936 show a production cost of close to $100 per acre (4). The two chief items entering into this figure are (a) labor, power and equipment, and (b) fertilizer materials.

Similar studies (20) made in recent years (1946–1949) show a rise of about 50 percent, the average annual cost of production for these years being $151.67 per acre. The chief factor in this increase was the marked rise in the cost of labor, power and equipment from $23.83 in the earlier period to $72.55 in the last three years. This increase was helped along likewise by increased fertilizer costs, from an average of $26.46 to $51.05 per annum per acre. However, a considerable part of this increase is accounted for by the greater age and size of the trees in the later period, obviously requiring more fertilizer and necessitating more grove labor, available only at mounting wages. The cost of spray and dust materials has tripled in these two periods, from $3.63 to $11.15, likewise accounted for by greater tree size,

as well as greater cost of some of the newer materials. The spread between these two periods is considerably greater than is shown when comparing the recent figures with the average of the previous 18 years (1931–1949), indicating that the rise has been gradual, largely therefore the result of economic factors affecting all types of industry.

Details of Expense and Returns

The averages for each item of cost, together with the returns for these two periods, are given below:

	3-yr. ave. 1946–1949	18-yr. ave. 1931–1949
Costs per acre:		
Labor, power, and equipment	$ 72.55	$ 36.34
Fertilizer materials	51.05	32.33
Spray and dust materials	11.15	6.19
State and County taxes	7.98	5.70
Miscellaneous	8.94	4.01
Total operating costs	151.67	84.59
Interest on grove valuation @ 6 percent	38.84	33.97
Total cost	$190.51	$118.56
Returns per acre:		
Returns from fruit	$247.81	$212.46
Net returns	57.30	93.90
Returns above operating costs	$ 96.14	$127.87

As to " interest at 6 percent " included in production costs, there is disagreement among economists as to the propriety of including this as an expense item. The interest charge here shown constitutes about one-fourth the whole cost of production. Whether or not the interest is charged as expense or regarded as income, the grower is the recipient thereof. For income tax purposes, it would hardly be allowed as a deduction.

In considering returns on grapefruit, especially on the per-box basis, it should be noted that grapefruit as a rule gives a higher yield per acre than oranges (21). Figures on orange and grapefruit groves in Florida for the 17 years 1931–1948 gave an average of 230 boxes per acre for oranges and 320 boxes for grapefruit. This figure, based on a limited acreage, is conceded to be well above the general average. Notwithstanding this higher yield of grapefruit, the returns per acre during this period were in favor of the orange acreage—$287 as against $196 for grapefruit—the per box price of oranges in the groves studied being about double that of grapefruit.

It should be pointed out that the low net return—$57.30 shown for the three-year period 1946–1949—included two low-price years and one year (1948–49) exceptionally good. The 1947–48 year gave a return $21.97 less than the operating costs, while the following year (1949–50) there was a favorable balance of $254.31. Figures for the 1949–50 net returns are not yet available, but should closely approximate or exceed the figure for the previous year.

In Texas the outlay for fertilizing materials is much less than in Florida, but this saving is largely counterbalanced by the irrigation costs.

New Plantings of Grapefruit

The effect of a year of good prices on planting of new acreage may be seen in the reported movement of citrus nursery stock during recent years (8). For 1947–48, 228,729 budded grapefruit trees moved out from Florida nurseries; the following year the figure was 252,401; in 1949–50, a year of high prices, 383,641 grapefruit were planted out. A small though considerable part of recent planting is due to the need for replacements in old or decadent groves. This is especially true in the sandhill areas where " slow decline " is causing increasing losses of grapefruit (and orange) trees budded on Rough lemon rootstock (27).

As to varieties represented in recent plantings, it is of interest to note that in 1949–50 nearly 75 percent of the grapefruit trees were of the pink seedless varieties, about equally divided between the Thompson and Ruby. The wisdom

of such a radical shift is a matter of some doubt, but it reflects the trend of recent fresh fruit prices.

Planting for the Future

In view of the rising population figures in the United States, it is of interest to estimate the new acreage needed annually to maintain or increase the present per capita consumption. With an expected annual increase in population somewhat in excess of two million, it is estimated that about 12,300 additional acres of citrus will be required each year simply to maintain the present rate of consumption, figuring production at 200 boxes per acre (24). The average increase in citrus acreage for the three-year period 1947–1950 was 13,500 acres, thus providing for a slight rise in per capita consumption, provided good production is maintained. For grapefruit alone it is figured that to increase the consumption by one fruit of 64 size per person there would be required 9,000 additional acres each year, assuming a production of 260 boxes per acre. The new plantings of grapefruit for the three years 1947–1950 amount to an average per year of slightly more than 4,000 acres, allowing for a planting of 70 trees per acre. It would seem therefore that the present rate of new plantings of grapefruit provide for no considerable increase in per capita consumption, especially in view of the reduction in acreage and production prospects in Texas, due to cold injury.

Grove Value

The spectacular increase in crop value in the last two seasons has of course attracted capital, and grove values have doubled and trebled in many cases. This situation has led economists to inquire into the factors involved and to arrive at a sane conclusion as to the safety of grove investments (22). It is pointed out that prospective investors should consider the average returns over a term of years instead of the profits of boom-time seasons. Investors are especially cautioned against purchasing a grove "on a shoestring", counting on future profits to carry the burden of grove care and interest charges. On the other hand, it is pointed out that crop reduction due to freezes, particularly in the grapefruit-producing areas in Texas, will favorably affect grapefruit prices for a number of years. Added to this is the stabilizing influence of the rapidly developing processing business, particularly the success of the newer concentrated juice products in meeting popular favor. The fact that "big business" has entered the field augurs well for the future, millions having recently been invested in processing plants equipped with the very latest machinery and employing research men of recognized standing. To insure adequate supplies of fruit, a number of these concerns have made large grove purchases in Florida, a fact which has been a prime factor in enhancing grove valuations. Both orange and grapefruit acreages have been included in these purchases, probably one-third being in grapefruit.

Transportation

Just what effect increases in transportation costs will have on future profits is problematical. One thing seems fairly certain from past experience; any increased cost will almost surely fall on the producer instead of the consumer. In the case of manufactured goods, this is not usually the case, but with fruit the consumer price unfortunately remains fixed within narrow limits, regardless of what the producer is receiving. This fact has long operated to the producers' disadvantage, and in years of bumper crops and low prices tends to restrict consumption.

Cooperation

In times of stress, especially in the field of horticulture, growers feel the

need of joint action to bring about more orderly marketing practices. Periodically ever since grapefruit became a popular fruit, efforts have been made to bring growers into a cooperative organization to stabilize the industry. These efforts, both in Florida and in Texas, have been only partially successful, the Citrus Exchanges in the two States contributing, however, much to the improvement of conditions, considering that their enrollment included only 25 to 30 percent of the growers. In California about 75 percent of the citrus growers have long been organized in their cooperative organization which, however, affects the grapefruit situation only to a minor degree.

The disastrous years following World War II, already alluded to, provided the stimulus in Florida for the organization of citrus growers on a State-wide basis. Approximately 90 percent of the citrus growers joined the Florida Citrus Mutual which has had a marked effect in bringing about orderly marketing. Besides the grower membership, the Mutual has enrolled 100 percent of the processors. An organization in Texas, called the " United Citrus Growers ", has been perfected which operates along the lines of the Florida Citrus Mutual. A new citrus code (5), raising the standard of maturity and emphasizing internal quality, has contributed much in the last two seasons to creating favorable public reaction. The green fruit menace, especially in grapefruit shipping, that for many years paralyzed the early market, seems to be no longer a serious threat. Some of those in the industry who most vigorously opposed the new citrus code have been won over by the results. The law courts have had to decide in some instances whether the new code could be maintained, but fortunately the decision has been favorable. It is not considered that the last word has been said on standards of maturity, for there are seasonal variations (11) as well as other variables, such as spray and fertilizer treatments, that may need consideration in the future.

The Florida Citrus Commission, a State agency established in 1935, has proved a potent factor in the improvement of marketing conditions. This agency is primarily concerned with advertising and merchandising, but finances research into problems as they arise in the industry. Applications for a license as a citrus fruit dealer must be cleared through the Commission, a valuable protection to the grower. Working in harmony with a State-wide cooperative organization, such as the Citrus Mutual, there is reason to look for more orderly marketing than in the past.

Besides the cooperating agencies already referred to, Florida since 1939 has had a Growers Administrative Committee and a Shippers Advisory Committee which operate to work out a marketing agreement for each season. This agreement must have the approval of the United States Secretary of Agriculture to become effective. It operates only on fresh fruit shipped in interstate commerce. While these agreements, formulated at the beginning of each season and adjusted from time to time, do not attempt to control the volume of fruit which may be shipped, they have an indirect effect by prescribing the grades and sizes that may be sent to market. These marketing agreements are not mandatory on an industry, being optional with the growers who must indicate a desire for the assistance they offer in bringing about orderly marketing. Since the fruit held back usually finds a ready outlet through the processors, no great hardship is experienced. With this type of control, together with the periodic shipping prorates recommended by the Citrus Mutual, orderly marketing seems possible of realization, avoiding the violent market fluctuations formerly experienced.

Summary

From the figures presented it is clear that grapefruit is primarily an American crop and especially important in the United States. The pummelo seems destined to continue its predominance in the Orient, though grapefruit introductions have been made with some prospect of securing a foothold. The age-old popularity of the orange does not seem to be affected to any extent by increasing use of grapefruit. In foreign lands grapefruit build-up has proved generally very slow.

Before World War II limited exports of grapefruit to western Europe met with such favorable reception as to give grounds for hope that there was opportunity for an expanding market in Europe. With the postwar food rationing and general austerity in food matters, this hope seems, for the time at least, to have faded out. Perhaps with the cutting down of transportation costs, grapefruit in processed form may eventually find a place in the European dietary.

The remarkable feature is that a fruit which only 50 years ago was practically unknown to the great mass of the American public—a hobby of the connoisseur—should in five decades have become so popular as to compete on fairly even terms with many other fruits handed down through the ages. Nothing quite like it has happened in the field of food utilization since the impact on food habits of the world when the discovery of the New World brought about rapid dissemination of the new American crops—corn, potato (both white and sweet) and beans, to mention only a few. The pineapple, also a native American fruit, perhaps comes nearest to rivaling the grapefruit in rapid appreciation, and its greatest use outside the tropics is in processed form. To what obscure agency we owe the origin of grapefruit we cannot be certain, but it is conservative to assert that both grower and consumer have derived much benefit thereby and horticulture has been vastly enriched.

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Utilization Abstracts

Furfural. Years ago furfural was a laboratory curiosity, largely imported from Germany at $1.50 an ounce. In 1922 the Quaker Oats Company made it available in commercial quantities from oat hulls at $2.50 per pound. Today it is manufactured in great quantities from corn cobs, and the Quaker Oats Company has recently opened a new factory at Omaha, Nebraska, to be a substantial supplier of furfural to Du Pont's new nylon factory at Niagara Falls.

" Manufacture of furfural at the new Quaker Oats plant is not complicated. The raw material is first ground and cooked with dilute sulphuric acid and steamed under pressure in large rotary digesters. The vapors are removed, condensed, and then travel through complex refining equipment to produce furfural having a purity of 99.5% or better ".

" In the first step, the pentosans, which occur naturally in the raw materials, are broken down to pentose sugars, such as xylose. (Pentose sugars are somewhat similar to ordinary household sugar, except that they are made of a five-carbon instead of a six-carbon atom). Dehydration of the pentose sugars produces the furfural ".

"A by-product itself, the manufacture of furfural has further by-products. After furfural has been extracted from the agricultural residues, the remaining material is processed into Fur-Ag and Furafil. They are dark brown, free-flowing powders, that are used as fertilizer conditioners and in foundries as a conditioner for sand molds. New uses are being developed in the lightweight fire brick and the plywood and plastic industries ".

In addition to corncobs, tens of thousands of tons of which are used every month in producing furfural, use is made also of oat, cottonseed and rice hulls; and in addition to nylon, at least 50 other manufactured products today use furfural somewhere along the line. (Anon., *Chemurgic Digest 11(1): 6. 1952*).

Cortisone from Sisal Waste. Hecogenin is a steroidal sapogenin in the leaves of sisal (*Agave sisalana*) and is being investigated in England and East Africa as a starting point for partial synthesis of cortisone. Sisal is widely cultivated in East Africa, on a scale yielding more than 100,000 tons of fiber a year, which would thus become a source of raw material for the manufacture of this drug if such manufacture is found to be economically feasible. (Anon., *Chemurgic Digest 11(1): 15. 1952*).

Citrus in West Africa, With Special Reference to Liberia

Although ample evidence has been gathered to show that citrus can be grown in many parts of West Africa, relatively little of it is cultivated there at present because of difficulties in transportation and communication. Shifting agriculture is still characteristic of the region, and tradition makes the growing of any introduced tree crop difficult.

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Introduction

In these days of potential food shortages and high prices, many people look to the world's great undeveloped tropical areas for the future production of foodstuffs. Undoubtedly, the potentialities of the tropics are very great. Nevertheless, the problems involved in raising food crops for export in the tropics involve numerous considerations, many of which seem very strange to the temperate zone farmer.

This paper is intended to explore some of the possibilities and to report some of the achievements to date in growing citrus fruits in West Africa, generally conceded to be one of the world's most primitive tropical regions.

While in charge of a program of plant improvement and introduction on land of the Firestone Plantations Company, Harbel, Liberia, the author introduced some 40 varieties and species of edible citrus into Liberia, partially as a result of a trip to the Agricultural Departments of the Ivory Coast, Nigeria and Gold Coast. Studies were made of citrus growing in each colony, and potentialities for the future were investigated. Some of the experimental studies on citrus propagation in Liberia have been reported (3).

Most of the following discussion refers to Liberian conditions with which the author is most familiar. Reference to the other West African countries is made for comparison.

Traditional Methods of Agriculture

Shifting agriculture is characteristic of most of West Africa. In most regions it is based roughly on a seven-year rotation, with modifications to suit local conditions. It is still custom in Liberia for the chief, after consultation with the elders, to parcel out the land to be farmed. All the brush is cut down at the beginning of the dry season, using only a cutlass (machete). The larger trees and palms are left standing. The dried brush is burnt over at the end of the dry season, which lasts from December to February, approximately, and seed is planted by the women at the commencement of the rains. Weeding is done by hand three or four times before the rice gets high enough to withstand competition. When the crop is harvested four to six months later, depending on the variety, the land is left fallow for about seven years. The crop is harvested and shared by the whole tribe, and everyone eats or everyone starves. Hunger is an ever-present

threat. Cassava (*Manihot esculenta* Crantz) is handled in almost the same way except that it is planted by cuttings and harvested over a longer period. This method of farming fits into the native's habits, his customs and his traditions. It has served him well for centuries.

Almost no deliberate planting of perennial crops is undertaken by the aborigines, although many tree crops—mango, avocado, oil palm, citrus, coconut, cocoa—have been shown to do well. The only exception to this rule is the Gold Coast where cacao planting, introduced by returned slaves from Spanish Guinea, was undertaken spontaneously by the natives, and where today a large part of the world's cocoa is produced.

Rice and cassava in Liberia and the Ivory Coast, and corn in the drier Gold Coast and Nigeria, constitute, along with the oil palm (*Elaeis guineensis* L.), 90 to 95 percent of the diet. A few yams, squashes, bananas, plantains, lima beans, peanuts and " greens ", such as sweetpotato leaves, cassava leaves and collards, make up the bulk of the remaining diet. Protein sources are mostly lacking, except for the African chicken, one of the toughest birds in existence, which is semi-domesticated, hunting its own food during the day and sleeping on the house roofs at night. Outside of an animal or snake occasionally trapped, the main portion of the native diet comes from agriculture, although some cattle are raised in the northern areas of Nigeria and the Gold Coast as well as in French Guinea.

Probably the determining factor in the native's habits of farming is that he is working on a marginal basis. Sometimes the native subsists on jungle fruits for two or more months before the " new rice " comes in. Naturally, he has neither time nor energy to spare on " cash " crops or any new crop. He must put to bear every ounce of energy he has to keep himself and his family on a subsistence level.

The aborigines of Liberia are said to be among the most primitive people in existence. Many examples could be given, the following serving to illustrate the problem. Many of these tribes have no written tongue, and their language structure changes rapidly. For example, while using a list of tribal words for forest trees compiled phonetically about 20 years previously (2), I found that the younger tribesmen no longer used those words. An old man had to be found to whom the words were still familiar. Such a change would almost be equivalent to each generation in our civilization substituting new words for oak or maple! The presence of many secret tribal societies which restrict the spread of knowledge also has a deleterious influence on the development of a progressive civilization.

Communications

There are very few roads in the interior. Communication is by jungle trails, and distances are often recorded by days, that is, as two-, four- or six-day travel. There is a new road from the coast of Liberia to the boundary of French Guinea and other roads are being constructed. In Nigeria there are a few into the interior, and there are some good roads in the Gold Coast, but most of them are confined to the large cities. There are only a few railroads, and they are of negligible importance so far as most crops are concerned, although the railroad from Kano to Lagos is now an important outlet for groundnuts. Few of the Liberian rivers, except for the Sapele, are navigable for any extent. This is also true of most rivers in West Africa. There are only a few good harbors along the coast, a new one at Monrovia and others at Abidjan, Takoradi and Lagos. There are bad sand bars along most of the coast which prevent large ships from coming in, and most articles must be loaded and unloaded by lighters. Much of the present develop-

ment in West Africa is concerned with building new roads and improving and enlarging harbor facilities. Air France and BOAC furnish air transport through most of this region.

Present Stage of Development

As one drives along the roads, or traverses jungle paths, it is common to see the semi-wild sour orange (*Citrus aurantium* L.) growing near native villages. It is a vigorous tree and it competes strongly with the second growth jungle trees. No cultivation is given to it. I have seen apparently the same species growing under like conditions in Liberia, Nigeria, Gold Coast and French Ivory Coast. Occasionally this orange produces mutant sweet forms, several of which have been selected in each of the colonies and Liberia (3). The origin of this tree is difficult to determine. It has obviously been present in West Africa many centuries.

The natives eat very few oranges, or indeed any citrus crop, but they may be purchased at the native markets during the season at prices ranging from one to four for a cent. They are very juicy, although somewhat acid in flavor, and are picked and sold green. Indeed, these oranges do not develop an " orange " color, even when fully ripe.

A few small plantations of citrus have been established in the French and British colonies (6, 8) and Liberia (3). Sweet oranges, grapefruit, tangerines, limes and lemons are now occasionally available in the native markets, although the natives themselves seldom eat citrus fruits, with the exception of occasionally eating an orange out of hand. They have no sugar and little salt, so their aversion to the more acid fruits is readily understandable.

Soils and Climate

Soils in most of the West Coast of Africa are a red lateritic gravelly clay and nearly all very acid. There is almost no humus formed, but where the soil is well drained it seems to support citrus adequately, especially if it is reclaimed directly from the jungle. Care must be exercised in using farm lands because some crops, such as cassava, deplete the land so much that it is not suitable for any crop for many years.

The high rainfall in Liberia and Ivory Coast (140–170 inches annually) and the dry season of three to four months do not seem to affect the growth of citrus adversely. In drier regions, such as the northern provinces of Nigeria, irrigation is necessary. Deficiencies in minor elements, mineral depletion or lack of water seasonally may adversely affect growth and vigor (6).

The French at Bingerville, Ivory Coast, and the British at Asuansi, Gold Coast, have collections of numerous varieties and selections as well as active breeding programs. Many of the best varieties have already been listed (3). One of the best varieties in the Ivory Coast is the Washington Navel. Considerable work is done here too with Bergamot oil (*Citrus bergamot* L.).

Although Washington Navel is very good in the Gold Coast also (6) and early growth was good in Liberia (3), it is not as vigorous as many of the other varieties. Pineapple and Rico No. 2 oranges, and Triumph grapefruit have made the best growth to date, although the plantings are not yet old enough to permit final evaluation. Other recommended varieties are the Marsh and Foster grapefruit, Mediterranean sweet orange, Satsuma and Mandarine (4). Several factors must be considered in the final evaluation of varieties, not least the method of disposing of the fruit. As pointed out below, canning or juicing will probably be the most successful method of marketing the fruit for some time, at least. In addition, vigor, resistance to disease, shipping

qualities and ease of propagation as well as other factors which may be important in each locality must be considered.

Propagation

Although, as previously pointed out, most of the citrus have been chance plantings of seed, various other methods have been tested. Propagation by budding is very successful (3, 5, 7). Herbaceous side shoot grafting is used in Nigeria (10). Although most citrus responds readily to any type of graft, cuttings do not root readily (3, 12). Marcottage is also successful, but slower and more cumbersome than budding.

Insofar as early growth is concerned, rough lemon or sour orange were found to be most suitable for stocks in Liberia, where no virus diseases have been encountered up to the present time. However, to avoid the danger of future attacks by virus, it would probably be safer to use rough lemon. The tangerine and grapefruit varieties tested for stocks exhibited relatively slow germination and growth, and the limes showed a tendency to excessive bud proliferation (3). Rough lemon was found to be superior to sour orange in the Gold Coast (6). Sour and sweet oranges are used as stocks in Nigeria (10). Some wild citrus have been used as stocks in the Ivory Coast, especially species of *Citropsis*, *Afraegle paniculata* Engl. and *Aegelopsis chevalieri* Swingle.

One method of budding which always yielded 90–95% success is that used with rubber (*Hevea brasiliensis* (Willd. ex Adr. Juss.)). The budder makes two longitudinal incisions in the stem of the seedling tree or stock, beginning 25 cm. or more from the base and cutting upward about four cm., the second incision about two cm. from the first. This method may also be used for top-working old trees. Both incisions are made to the depth of the cambium. A third cut is made joining the first two at the top; during the rainy season the third cut may be made at the base. The bud is removed from the budstick by a single deep cut which also removes part of the wood. The wood is then peeled off, care being taken not to bend the bark, and the bud is shaped to fit the aperture on the stock exactly, with about one mm. space on each side and up to four mm. at the top, where contamination might occur. The bark flap of the stock is gently pulled back and the bud inserted. The flap is replaced, wrapped with string, taped and waxed at the top of the tape. After 18 to 21 days the tape is removed and the bud examined. If it is still living, it is marked, re-examined ten days later and, if still alive, is considered successful. The seedling stem may be cut off when ready to transplant, although cutting back the stem a week or so before transplanting helps induce sprouting of the bud (3). In many instances the grafted buds fail to sprout for three or four months after transplanting unless treated in this way. The method found most satisfactory is to cut back in the nursery and wait to transplant until the buds have swelled and begun to elongate.

Budwood which has been delayed in transit and has become too dry to bud may be "rejuvenated" by planting as cuttings in a bed of moist sand under light shade. Buds taken as long as three months after these cuttings were placed in the sand gave excellent results when budded by the ordinary methods, even though nearly all of these cuttings eventually died without forming roots (3).

This is a rather useful technique, especially in the tropics where it is often necessary to ship budwood long distances with uncertain means of transportation.

The lime tree, an excellent variety, which bears a crop of small limes almost the whole year, is propagated by seed in Liberia. It is now grafted on rough

lemon in Nigeria because of a virus infection (9).

Harvesting

In Liberia the oranges and limes bear fruit the fourth or fifth year. The fruit is picked by hand when "full" (mature) and carried to market as fresh fruit. Baskets woven of raffia are filled with fruit, placed on the head and carried perhaps several miles to the market. A native may go a long distance, five to ten miles, to sell 40 or 50 cents worth of fruit.

There is no attempt at canning, juicing or preserving in Liberia, although in the French Ivory Coast and the Gold Coast (5) some orange and grapefruit juices are prepared. There is a citrus juice bottling plant at Cape Coast district in the Gold Coast, and fruit squash and juices are produced in Nigeria (10). There is a pilot plant, now canning Marsh seedless grapefruit sections in Ibadan, Nigeria, utilizing fruit grown by local farmers in the vicinity.

The industry in Nigeria is in some ways representative of the other African countries, and is perhaps somewhat more advanced. The difficulties experienced there are in many ways the same that may be expected in other parts of West Africa. During the war the internal trade was high but there was a postwar surplus. Further expansion of citrus plantations depends on better markets (11). Attempts to sell grapefruit in Europe were unsuccessful because the fruit was not up to modern standards as regards appearance. Although of high eating quality, it fails to sell on the European continent in competition with more carefully sprayed, harvested and packed fruit. Samples of orange, grapefruit, lemon and lime juices have been tested. A large part of the production will probably go into juices at least temporarily (10). Under the present conditions of isolation, poor transport, and shipping difficulties, it is likely that juicing or canning will be the most successful method of marketing the fruit produced for some time to come in all parts of West Africa.

Diseases and Pests

The citrus moth has occasionally done severe damage in the Gold Coast. A virus disease attacks seedling limes and is overcome by grafting on rough lemon (6). *Aphis taveresi* is the vector of one strain of virus, which causes one-sided death coupled with veinal fleckings on the young leaves, and another which causes conspicuous dwarfing and usual veinal symptoms and subsequent death. Most kinds of sweet citrus and rough lemon are symptomless carriers (1).

Aphids and scale are common pests but are generally not serious. A leaf disease (*Phytophthora citrophthora*) is often present. Adequate control of this disease is obtained with one or two sprayings of Bordeaux mixture.

Sporadic outbreaks of the coreid bug (*Leptoglossus membranaceus*) have occasionally caused severe damage in Nigeria. This pest breeds on *Citrullus vulgaris* as an alternate host and is susceptible to DDT (11).

Gummosis of oranges and other citrus and a few cases of psorosis on tangerine have been reported (4).

Although few diseases have been reported on citrus in Africa, this is probably because no large plantings have been made in most regions. If more areas are planted it is almost certain that more trouble with diseases and pests will be encountered.

Discussion

The impact of twentieth century civilization and the resultant social ferment in Africa, as in many other primitive areas, has already drastically affected tribal unity. The many tragic effects of European civilization in destroying,

often unwittingly, the tribal organization which has functioned for many centuries, without providing an adequate substitute, need not be discussed further here, except insofar as they affect agricultural development.

Roads have been built which have opened up remote regions heretofore accessible only by foot, and more are rapidly being built. Motor cars and trucks are whizzing by villages, the inhabitants of which in many cases may have never before seen even the simplest modern-day equipment. The intricate tribal organization does not withstand the impact of modern civilization. The authority of the chiefs is flouted by the youths, rituals are forgotten or ignored and the resultant instability and restlessness do not contribute to a progressive agriculture.

Citrus production may be expected to expand slowly as internal demand becomes greater. As transportation facilities improve, shipping of fruits will be easier and more rapid as well as less damaging to the fruits. Juices or preserves appear to be the most likely outlet for citrus for some time to come. It may be many years before marketing facilities or farming practices permit shipment of saleable fresh fruit to Europe or America, although many well-known varieties of citrus can be successfully grown, and many natural mutations and crosses have been selected for propagation.

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Utilization Abstract

Scabrin — New Botanical Insecticide. In Mexico the natives use a plant, known to them as "peritre del pais" (native pyrethrum), against flies and other household insects. This plant was identified only in 1947 as *Heliopsis longipes* and, so far as is known, occurs only in Mexico. Chemists in the Bureau of Entomology and Plant Quarantine have isolated the toxic principle of this plant as N-iso-butyl-2,6,8-decatrienamide and have found it as toxic as pyrethrins to house flies. Similar toxicity was found in the roots of three species of the same genus growing over a great part of the United States—*H. scabra*, *H. gracilis* and *H. parvifolia*. The compound isolated from these species, closely related to the active constituent in the Mexican plant, has been named "scabrin". It occurs, especially in the roots of *H. scabra*, as a viscous yellow oil and can be removed completely by extraction with low-boiling petroleum ether. This new insecticide has been found to be about two and a half times as toxic as pyrethrins to house flies, somewhat toxic to warm-blooded animals and inhibitory to the growth of several microorganisms. (R. C. Roark, *Soap & San. Chem.* *27(3): 125. 1951*).

The Use of Wild Plants in Tropical South America[1]

Such plants have provided the natives since pre-Columbian times not only with food but also with shelter, salt, basketry, ornament, cloth, gums, unguents, poisons, medicines and other useful products.

CLAUDE LÉVI-STRAUSS

Introduction

It is not always easy to distinguish between wild and cultivated plants in South America, for there are many intermediate stages between the utilization of plants in their wild state and their true cultivation. Steinen (1894) gives several examples of these transitional stages in Central Brazil: among the tribes of the upper Xingú River, for instance, he saw paths lined with piqui trees, which generally grow wild, and with mangaba and urucú trees that had been transplanted near the settlements and artificially irrigated. On the other hand, actual cultivation was very rudimentary. One native tried to plant discarded matches; others blew on tobacco plants to insure their growing. The Tupí-Cawahíb of the upper Madeíra River gather the seeds of an unidentified wild grass that grows in the forest, and in order to facilitate the harvest they tie together several stems before they are ripe, so that the seeds of several plants fall on the same spot and pile up in small heaps. The tribes of the Pimenta Bueno River leave on their clearings some palm trees, in the bark of which edible grubs develop. These are the first steps toward cultivation. Roth (1924) writes: "It must be borne in mind that in the clearing of the forest the Indian will usually save from destruction any economic palms or edible fruit trees. Dance says that kushi ants will not have their nests near a cunaparu (*Phyllanthus* sp.) plant, the milky juice of which is acrid and insufferably irritant, and it is for this reason that many fields contain two or three of these plants".

In the tropical forests, gathering as well as cultivation may be highly developed, for the utilization of wild plants often entails refined exploitative techniques that require far more than mere collection of wild foods. Few people, for example, have made a staple of a food as highly poisonous as manioc. The great skill shown in utilizing the vegetable environment is also shown in the various uses made of the same plant. For example, manicoba (*Manihot dichotoma, M. glaziovii, M. heptaphylla, M. piauhyensis, M. violacea*) is a source of poison, of rubber (borracha do Ceará, de Jequié, de Manicoba) and of food, its grated roots being consumed as flour after the poison has been extracted and its oily seeds being eaten (Pio Corrêa, 1909). *Protium heptaphyllum* provides a balsam, a rosin for glazing pottery and a drink, the last prepared from its fruits. The preparation of several wild foods requires various complicated processes, such as those for preparing bitter manioc and green-heart seeds (*Nectandra rodioei*). Roth (1924) describes the lat-

[1] Reprinted from Smithsonian Inst., Bur. Am. Eth., Handb. So. Am. Ind. Vol. 6: 465–486. 1950.

ter: "The seeds are grated and put in fresh water, and a matter precipitates similar in appearance to starch. It is repeatedly washed to lessen its bitterness, which is never lost entirely. It is then mixed with rotten wood, pounded previously and sifted, and those who have it in their power mix a little cassava flour with it ".

In tropical South America the general cultural levels are determined historically rather than by the local plant resources, for no fundamental culture traits appear to depend directly on the botanical environment. Pine nuts in southern Brazil and Brazil nuts in northern Brazil are two important foods not found elsewhere, yet no special aspect of the culture of the tribes exploiting them can be directly related to their exploitation; conversely, no special traits are found in the areas lacking these nuts. Fibers from palm trees (*Astrocaryum* sp.) and from a bromeliad (*Bromelia* sp.) are used indifferently in the same area, though palm fibers are more commonly used in the north and *Bromelia* in the south, and differences in materials and techniques between these two areas are insignificant. Nordenskiöld (1924) is responsible for the notion that wild plants " set their stamp on the culture of the Indians ". The example which he gives is unconvincing. He writes (1919): " Thus, in 1909 I came across a couple of Guarayú Indians on the Rio Parapetí. They had long portable baskets woven out of paripinnate palm leaves. As we entered the Parapetí territory the baskets became worn out, but as there were no paripinnate palms in this part, they could not make new ones. If, for any reason, the Guarayú tribe were forced to migrate from their present region to the Parapetí region they would have to change the type of their portable baskets ".

The statement draws its importance from a former statement by Nordenskiöld that " fanshaped leaves are of little use, while paripinnate are so useful ". As a matter of fact, the Guiana Indians used both fan-shaped and paripinnate palm leaves, and both kinds have about equal value in basketry, so that the presence or absence of one or the other is of little consequence. The difficulty of the Guarayú mentioned was culturally, not environmentally, caused.

The facts, indeed, point in a quite different direction. Many vegetal species in South America have widespread distribution, and the same vegetal environment surrounds tribes far distant from each other. For purely cultural reasons, these tribes make a very different use of their environment. The distribution of *Ficus*, *Bombax*, *Bertholletia* and *Cariniana* does not explain the presence or absence of bark cloth; the two great centers of bark cloth, *i.e.*, the upper Amazon and northeastern Bolivia, are cultural—not geographic—centers. The failure of Central Brazil to develop this industry was not because of lack of convenient material; the Bororo, for example, make bark cloth, although only for the perineal band of women's dress.

The striking fact is that, far from depending wholly on the natural environment, South American Indians throughout the tropical area show exceptional ability to discover substitutes wherever a vegetal species is lacking. For example, Pardal quotes the substitution of the decoction of the bark of pariah (*Simaruba*, *Simaba*, *Picrasma*) for urucú (*Bixa orellana*) in the southern part of the tropical area where it is difficult to grow urucú. The principle of body ointment and adornment is preserved; the plant varieties used for this purpose differ. The same is true of the balsams: in the south, *Copaifera langsdorfii* replaces *Copaifera multijuga* of the Amazon; and when the Leguminosae listed in pharmacopoeia as yielding benzoin are lacking, they are replaced by either *Myrocarpus*

or *Liquidambar* (Pardal, 1937). For the varnishes, *Protium heptaphyllum* served in the north, *Bulnesia sarmienti* in the south; for stimulants, guaraná in the north, maté in the south; for weapons, arrow shafts are made either of taquara (*Chusquea* sp.) or of *Gynerium sagittatum*, according to the lack of one or the other in a definite region. The Chané, who lack even the latter, have replaced it with *Arundo donax* (Nordenskiöld, 1920).

It is also difficult to agree with another statement by Nordenskiöld (1919), who says, " that the abundance of wild fruits, as well as the intensive dryness during part of the year and the flood during another part, account for agriculture being so underdeveloped in the Chaco ". Nowhere in South America has the abundance of wild resources impeded agriculture. On the contrary, the various independent places of origin of agriculture postulated by Vavilov (1926, and after Sauer, 1937) all have many kinds of wild foods, and in South America incipient farming and developed exploitation of wild resources tend to be associated rather than mutually exclusive. That the abundance of wild foods does not preclude farming is shown in the case of Guiana (Roth, 1924): " One Indian (Akawai) will clear and, with his wife, plant 2 or 3 acres in as many weeks, and 7 or 8 acres will supply them with a year's food, so that 10 or 12 weeks in the year is absolutely all that is required for actual labor, and the rest of the time remains for pleasure, hunting, and fishing ".

In the mind of the South American Indian, the principal geographical distinction is that between the savanna and the forest. The first is unsuitable for cultivation as well as for gathering and collecting wild foods; both animal and vegetable life on it are sparse. The forest offers abundant wild plants and game, and its moist soil is fertile. The stupidity of the deer which in a myth tries to cultivate manioc in the savanna filled the Bacaïri with mirth, according to Steinen (1894).

Cooper (1942*a*, 1942*b*) has suggested that the tropical area of South America could be divided into two subareas, according to the level of cultural achievement: ". . . the Orinoco-Amazonian farmers and the scattered tribes subsisting by a purely collecting economy or else with a rudimentary or recently acquired horticulture ". The same author suggests that, considering the fairly close correlation between the cultural groups and the natural areas, the first group should be called " silval " and the second " marginal ", the latter subdivided into a " savannal " and an " intrasilval " subgroup. Irrespective of the usefulness of such a classification for practical purposes, it is necessary to keep in mind that farming always accompanies, and is never a substitute for, the exploitation of wild resources. The silval area is not only an area of farming but is one with abundant wild vegetal food and industrial plants. Moreover, few tribes subsist solely by a collecting economy, and they are distributed at random in such varied places and in such geographic environments (the forests of Paraguay and the Guajira Peninsula, for instance) that their lack of farming seems to depend much more on the cultural history of each separate region than on geographical factors. Finally, there is no reason to consider that the rudimentary agriculture of the great majority of the savanna tribes was recently acquired. These remarks lead to the following conclusion: The characteristics both of farming and of the exploitation of wild plants in South America show that their place of origin was the tropical forest or the banks of the northern streams which are naturally bare and remain uncovered by water during most of the year (Roth, 1924). This silval culture, based alto-

gether on farming and on the exploitation of wild resources, which requires as much skill as farming, is the only genuine culture of tropical South America.

All South American tribes clung to the forest whenever they were forced to change their habitat. This was true of the Tupí during their long and widespread migrations. Petrullo (1932) noticed that the inhabited area of the Xingú River begins only at the points where the gallery forest becomes a true rain forest spreading inland. The savanna, where manioc does not grow, is always avoided and probably was occupied only by tribes driven into it by stronger populations. In the savanna the horticultural pattern was partially retained by turning to the best possible account the strips of gallery forest along the streams. It was sometimes improved, as shown by Nimuendajú's discovery among the eastern Ge of cultivated *Cissus* not reported elsewhere. Farming was abandoned in favor of hunting (Bororo) or of collecting and gathering wild foods, or of both. But there is little doubt that all non-horticultural South American tribes were formerly farmers. The well-known text by Karl von den Steinen (1894) about the behavior of the Bororo in the presence of the gardens opened by the Brazilians is of little weight when compared to the fact that these very Indians were acquainted with an elaborate harvest ritual. Farming might have been forgotten among some Bororo as a result of the abundance of game along the marshes, but agriculture was not new to them.

Utilization of wild foods exists in the tropical area on two levels: a basis level, in which it coexists with farming and is centered in or around the forest, and a subsidiary level, which is one of collecting brought about by compulsive adaptation to the savanna and which often remains partial and is always secondary.

Palms

Several species of palm played an outstanding part in native cultures. Thus, for instance, Gumilla (1791) remarks that the muriche palm (*Mauritia flexuosa*) was the mainstay of the Warrau economic life. From it these Indians obtained wood for their pile dwellings, fiber for their clothes, ornaments, hammocks and fishing tackle, starch for making bread, sap for their wine, the fruits for a sort of punch, and leaves for their baskets. They also extracted large edible larvae from its decayed trunk.

The pupunha, or peach palm (*Guilielma gasipaes*), is a palm long cultivated by the Indians, though it still grows wild. The edible fruit of the cultivated tree lacks the thick shell characteristic of the wild varieties. Palms are semicultivated, for wild palm trees are often spared on a clearing and tended together with cultivated plants.

About 20 genera of palms were widely used, being exploited for the following purposes:

Edible Fruits. Several genera yield nuts which are edible after the shell of the fruit has been broken. Most important in the native diet are the uaguassú (baguassu, babassu), or pindoba nut (*Orbignya speciosa*), which is rich in oil, and the nuts of the genera *Acrocomia, Astrocaryum, Attalea, Catoblastus, Cocos, Copernicia* and *Maximiliana,* which have different food values.

With other species it is not the nut but the fleshy substance surrounding it which is consumed. Both the nut and the flesh are eaten of the mucaja or bacaiuva (*Acrocomia*), but only the flesh is eaten of the caranai (*Mauritia horrida*) and the burití (*Mauritia vinifera*) in central and western Brazil, and of the mirití or ite (*Mauritia flexuosa*) in Amazonas and Guiana. This fruit is all-important in the diet of many tribes because of the many vitamins contained in the mush prepared with its orange-yel-

low pulp. Thevet (1878) describes the uricuri or buri da praia (*Diplothemium maritimum*), a small tree with edible fruits relatively abundant between Rio de Janeiro and Cabo Frio.

The fruits of several palm tree genera are used only to prepare beverages or mushes. The most important are assai (*Euterpe oleracea, E. precatoria*), manicol (*Euterpe edulis*), bacaba or turu (*Oenocarpus distichus, O. bacaba*), lu (*Oenocarpus* sp.), patua or pataua (*Oenocarpus patua*), aeta (*Mauritia flexuosa*), kokerit or anajá (*Maximiliana regia*), awarra or jawari (*Astrocaryum tucumoides*) and marajá (*Bactris minor*). In most cases the ripe palm fruit is soaked in lukewarm water—boiling water would harden instead of softening them—and then the pulp is separated from the shell or kernel and made into a thick, oily, fragrant drink which has a high nutrient value. These drinks may be consumed immediately or after standing a night, which gives them a slightly sour taste. Sometimes manioc flour is added to them.

Palm Wine. The sap of *Mauritia vinifera* is drunk fresh or slightly fermented. It is collected in a trough-shaped cavity dug in the trunk of a felled tree (Warrau). The coroxo wine is made from the fruits of *Acrocomia aculeata*.

Palm Cabbage or Palmito. Palmito, *i.e.*, the terminal shoot of several species of palm, is one of the few fresh vegetables in native diet. It is eaten raw, broiled and sometimes boiled. The palmito of almost all palm species can be consumed, but some have a bitter taste, as for instance *Acrocomia*. The Brazilian Indians show a marked preference for the palmitos of *Euterpe, Cocos* and several species of *Iriartea*. In the Chaco the Indians consume the palmitos of the caranday (*Copernicia cerifera*).

Starch. The Warrau extract starch from *Mauritia* in the following manner (Roth, 1924): " When an ite tree begins to fructify it is cut down, a large slice is cut off one side, and the stringy substance of the interior is cut into shreds, the remainder of the trunk serving as a trough, in which it is triturated with water, by which is disengaged a considerable quantity of starch. The fibrous particles are then extracted, and the sediment, or aru, formed into molds like bricks. This is spread out on stones or iron plates over the fire, and makes a very nutritive but at the same time unmasticable bread ".

This starchy food is known under the name of " sagu " in northern and eastern Brazil (Pio Corrêa, 1909). The Guayakí extract a starchy flour from the pindo palm (*Cocos romanzoffiana*) (Vellard, 1939).

Oil. Oil can be extracted from several palm fruits by crushing and boiling them. It may be used in cooking, for lighting purposes or in medicine; but more often the Indians mixed it with urucú or some other pigment to smear on their bodies. The palm species which produce oil are *Orbignya speciosa, Astrocaryum tucuma, A. tucumoides, Attalea speciosa, Maximiliana regia, Oenocarpus bacaba* and *O. patua*.

Salt. The ashes of the fibers and of the fruits of some palm trees, such as jara (*Leopoldinia major*), and of the leaves of some other species, such as *Mauritia flexuosa*, are boiled, and the decoction is allowed to evaporate in order to obtain a brownish powder which is used as salt. Staden (1928) saw and describes the whole process among the ancient Tupinamba. From the ashes of a palm trunk they make a solution which they boil until the salt is separated. " It tasted like salt and was grey in colour ".

House Thatching. Palm leaves are the most common plant materials for thatching the roofs and frames of native huts. The method of thatching depends upon the nature of the leaves. If the fronds are paripinnate, such as those of the an-

ajá, the leaflets are made to fall limp and loose by tearing loose the "eye", *i.e.*, the internal articulation of the leaves with the midrib. The palms are attached horizontally to the purlines, overlapping like tiles. For fan-shaped leaves, the techniques are more elaborate. The ancient Tupinamba parched the leaves of the pindoba over a fire and then plaited them before thatching their huts. Among the Guiana Indians, palm leaves preferred for thatching are the truli or bussú (*Manicaria saccifera*), caranai (*Mauritia horrida*), burití or ite (*Mauritia vinifera, M. flexuosa*, or *M. armata*), dallibana (*Geonoma baculifera*), ubim, *Geonoma elegans, G. paniculata, G. pohliana, G. schottiana*, anajá or kokerit (*Maximiliana regia*), manicol (*Euterpe edulis*), turu or bacaba (*Oenocarpus bacaba*), assai (*Euterpe oleracea*), etc. (Roth, 1924).

Basketry. Max Schmidt (1905) classifies twilled basketry in two classes, depending on whether fan-shaped or paripinnate leaves are used. He believes that many decorative motifs in the art of these Indians come from the basketry patterns that are inevitably produced by using fan-shaped burití palms.

Paripinnate leaves, such as those of *Maximiliana regia, Orbignya speciosa, Orbignya phalerata* (cusi of the Chaco), two species of *Astrocaryum* (respectively, awarra and akko-yuro in the Guianas, tucúm and tucumá in eastern Brazil; murumuru or *Astrocaryum murumuru* in the Amazon) and several species of *Desmoncus* (kamwarri or jacitara) are particularly suitable for making fans, mats and temporary carrying baskets.

With the fan-shaped leaves of the burití or ite palm, the Indians of eastern Brazil weave fire fans, containers, trays and rectangular baskets characterized by geometrical patterns.

Twine, Cords, Strings. The young unopened leaves of *Mauritia flexuosa* reduced to the cortical strips and soaked in water for several days are made into cords which have many uses in the Amazon Basin. The fibers of several species of *Attalea*, mainly those of piacaba (*A. funifera*), or chiquichiqui (*Leopoldinia piaçaba*) provide material for thick or small ropes. The name "tucúm" is given to several palm trees, mainly in *Astrocaryum* and *Bactris*, particularly *B. setosa*, which give excellent fibers for strings and ropes used for making hammocks, nets etc. These species are as important to the Indians of the Amazonian or Orinoco Basins as the bromeliad known as "caraguatá" are to the Indians of the Chaco. The name "jupati" is given to plants of the genus *Raphia*.

Wooden Objects. Posts, fences and palisades are often made of catizal or paxiuba wood (*Socratea exorrhiza* and *S. durissima*). The natives of eastern Bolivia and the upper Amazon make their bows of the hard black wood of chonta palm (*Guilielma insignis*). Clubs and spears are often carved of the same wood. The stem of paxiuba (*Socratea exorrhiza*) serves to encase the *Arundinaria* tube of the blowgun. The gigantic trumpets of the Uaupés River Indians are made of sections of paxiuba palm (*Socratea exorrhiza*) wrapped with long strips of iebaru (*Eperua grandiflora*). Finally, the wax of the carandai or carnauba palm tree (*Copernicia cerifera*) must be mentioned here. This species is especially important in northeastern Brazil. Nordenskiöld (1929) has shown a Chacobo manioc grater from Bolivia. It consists of a section of the trunk of a thorny palm tree. Often, to make a grater, thorns are imbedded in rows in a wooden plank.

Beads and Ornaments. The black polished shells of the small nuts of *Astrocaryum* are practically everywhere carved into beads, earrings and other types of ornaments. The wood of other palm trees is occasionally used for miscellaneous purposes. These are pati

(*Orcus* sp. and *Cocos botryphora*), buri and buri-assu (*Diplothemium caudescens, D. campestre*), aracuri (*Cocos coronata*), curua or acuri or auacuri (motacu in the Chaco), several species of *Attalea* (*A. speciosa, A. phalerata, A. princeps, A. spectabilis*), buritirana (*Mauritia aculeata*), etc.

Timber Wood

The number of tree species used by the Indians in their industries is so large that a complete list would fill a volume. Here are enumerated the names of species most frequently mentioned in the old literature dealing with the culture of the Brazilian Indians.

Several kinds of aroeira are used: aroeira branca (*Lythraea moleoides, L. brasiliensis*), aroeira molle (*Schinus molle*, which also yields the so-called American mastic) and aroeira vermelha (*Schinus terebinthifolius*).

Cedro comes from several families of plants: imbuia (*Bignonia* sp.); cabreuva (*Myrocarpus* sp.); acareuba (*Calophyllum brasiliense*); conduru, a red wood (*Brosimum conduru*); ubiraeta or iron wood (*Caesalpinia ferrea*); barauna (*Melanoxylon brauna*); jurema (*Pithecellobium tortum* and *Mimosa verrucosa*); ivory white or pau marfim (*Balfourodendron riedelianum*); red guarabu (*Peltogyne confertiflora*); black caviuna or jacaranda (*Dalbergia nigra*); Vinhatico, a yellow reddish wood (*Plathymenia reticulata*); and piquihi (*Caryocar barbinerve*). The genera *Tecoma* and *Couralia* provide various reddish and blackish woods. Jatahi and jatoba are trees of the genus *Hymnenaea;* macarandiba is *Lucuma procera;* guapeveira is a species of *Chysophyllum;* andira or pau de morcego is *Andira rosea* or *A. fraxinifolia;* jequitiba is *Couratari brasiliensis;* sucupira is *Bowdichia virgiloides* and *Pterodon pubescens;*arariba or araruva, a striped wood, is *Centrolobium robustum;* urucurana is *Hieronymia oblonga* and a species of *Alchornia*.

In addition, several palms, especially in the genera *Orbignya, Astrocaryum, Guilielma* and *Iriartea*, are used for hut frames, weapons, fences, etc.

Some woods are traditionally used for making specific objects. Clubs and macanas are generally carved of the hard wood of various Leguminosae, especially purpleheart (*Copaifera pubiflora, Caesalpinia* sp., and *Myrocarpus* sp.), snakewood (*Brosimum aubletti*) and amara (*Schwartzia tomentosa*). The Tupinamba used ibiratinga (*Funifera* sp., of the family Thymelaeaceae) to make the staves of their spears. The Guiana Indians made their best paddles of the fluted projections of the yaruru or paddle wood (*Aspidosperma excelsum*); the Tupinamba of *Genipa americana* or of uaca (*Ecclinusa ramiflora*).

The light woods or gameleiras include a great many species of *Ceiba* (*e.g.*, copaubucu, *Ceiba erianthos*) and *Ficus*, as well as ubiragara (barriguda or barrigudo tree, *Cavanillesia arborea*, and several other Bombacaceae), umbaubeira (*Cecropia adenopus*), apeiba (*Apeiba* sp.) and paraparaiba (*Cecropia* and *Triplaris*).

These light woods are used mainly for making ear or lip plugs (Suya, Botocudo, etc.), cylindrical containers for feathers and ornaments (Bororo, etc.), rafts or jangadas (on eastern Brazilian coast, *Apeiba* sp. or apei is used), and canoes (*Cavanillesia arborea* and *Ceiba pentandra*).

Canoes. In Guiana, canoes and corials were made out of the following trees: siruaballi (*Nectandra* spp.), tenyari or mara (*Cedrela odorata*), purpleheart (*Copaifera pubiflora*), kabukalli (*Goupia glabra*), itenalli (*Vochysia tetraphylla*), silk-cotton tree (*Ceiba pentandra*), crab-wood (*Carapa guianensis*), incense tree (*Protium guianense*), *Dimorphandra mora*, and several species not yet identified. In northern Brazil canoes were dug out of the trunks of *Cedrela odorata* and *Ceiba pentandra*.

The Indians of central Brazil make their canoes from the bark of jatoba (*Hymenaea courbaril*). The same bark was probably used by the Tupinamba. The Tupí dug canoes out of a member of Bombacaceae or *Ficus doliaria*. *Iriartea ventricosa* is used for the same purpose.

Bows. In the Guianas bows are made from at least half a dozen different timbers. Those which have been identified are the purpleheart (*Copaifera pubiflora*); burakura, burukuru, burokoro, leopardwood or snakewood (*Brosimum aubletii*), and *Lecythis ollaria*. In Brazil the most common bow wood is *Tecoma conspicua*, called for that reason " pau d'arco ".

Perfumed Woods. Beads of necklaces are often carved from fragrant woods. These are carunje (species of *Ocotea* and *Nectandra*), vanilla (*Vanilla* sp.), cinnamon wood or anhaybataa (*Pseudocaryophyllus sericeus, Cinnamodendron axillare* and *Capsicodendron pimenteira*), rosewood or jacaranda (*Dalbergia nigra*), and pau santo (species of *Bulnesia* and *Zollernia*).

Certain other woods have an unpleasant odor: ubirarema or canella merda (*Nectandra myriantha*), pau d'alho (*Gallesia scorododendrum*) and several vines which smell like garlic (*Lundia longa, Clytostoma noterophilum, Segueira floribunda, Adenocalymna alliaceum*, etc.).

Fibers

Fibers used by tropical Indians in their industries come mainly from palm trees. Fibers are also extracted from several of the Bromeliaceae, mainly *Bromelia fastuosa* and *B. serra*, which are known as " caraguatá ", " gravata " (Tupí), " chaguar " (Quechua), " pita ", " kuraua ", etc.

In the Guianas and in many regions of Brazil, the Indians utilize the fibers of both palm trees (tucúm) and of bromeliads, though the first give thinner and better strings. In the Chaco and southern Brazil, the Indians employ almost exclusively fibers of Bromeliaceae.

In Colombia, Ecuador and Perú, the Indians obtain the fibers for their ropes and textiles from agave.

The Brazilian Indians use vines and creepers of many species for ropes, cables or strings. Those called " cipo " belong to many families and genera. Cipo-embé is the adventitious root of a plant of *Philodendron*. The timbó group includes thinner varieties of vines (*Serjania* and *Paullinia*) which may be twined or plaited. Timborana (*Lonchocarpus* sp. and Malpighiaceae sp.) serve the same purposes. In the northwestern parts of South America, the name " bejuco " is given to *Vitis tiliifolia, Trichostigma octandrum, Entada gigas*, etc.

Roth (1924) lists nibbi or sippi, mamuri and muna (*Carludovica* sp.) as bushropes which in their natural condition may be used as twines.

Paina (*Chorisia speciosa*), embiriti (*Bombax munguba*) and goayaimbira (*Cecropia concolor*) are trees which yield a fibrous substance used by the Indians. The cotton-like wads which the Indians attach to the buts of blowgun darts come from the fruits of *Bombax globosum* and *Eriodendron samauma*.

Bark Cloth. Bark cloth may be obtained from several species of trees. In eastern Bolivia and on the upper Amazon the Indians use bark of trees of the genus *Ficus*, which are known in Bolivia as " bibosi ". From the Guaporé to the Orinoco River cloth is made from the bark of species of *Bertholletia* and *Cariniana;* in the northern parts of the continent and in the West Indies, from cabuya (*Fucraea gigantea*), majagua (*Hibiscus tiliaceus*), memiso (*Muntingia calabura*) and manbarakrak (*Lecythis ollaria*); and in eastern Brazil, the bark of embiriti (*Bombax munguba*).

Miscellaneous

According to Steinen (1894), the Xingú River Indians cultivated a wild

grass which they used as razor blades. The fruit of a member of the Bignoniaceae (pente de macaco, *Pithecoctenium echinatum*) was used as a comb by the Tupí and other tribes. The Tapirapé use the fruits of a grass (capim flecha, *Streptogyne crinita*) as tweezers for plucking hair (Baldus, quoted by Hoehne, 1937).

Since the two more important fruits used as containers were cultivated (*Crescentia cujete,* cuia, güira, and *Lagenaria siceraria*), only the shell of *Lecythis blanchetiana* (one of the numerous sapucaia nuts) and the hollowed-out seeds of several palm trees (*Astrocaryum*) and the staunch flour containers made from the leaves of *Heliconia* and *Calathea* may be mentioned here. The leaves of *Heliconia bihai* and of several kinds of *Geonoma* were also used for roof and wall thatching.

The calabashes of the upper Rio Negro are lacquered with a decoction of carayuru (Bignoniaceae) and cassava leaves sprinkled with human urine (Roth, 1924).

In addition to numerous palm nuts, a great many nuts (genera *Bertholletia* and *Lecythis*) and seeds (olho de cabra or comedoi: *Ormosia nitida, Omphalea diandra, Myroxylon toluiferum,* and others) are used as beads in necklaces, tassels and the like. Several hard-shelled seed pods, including *Thevetia peruviana* and *Juglans* sp., were made into rattles for accompanying songs and dances. Also used for rattles in Guiana were many nuts and seeds known only by their local names: kawa and cerewu or cerehu seeds and caruna and ahouai nuts. The hollow cylinders used to strike the ground as a dance accompaniment are made of trumpet wood (*Cecropia*) or bamboo (*Gadua*). The drums of the Orinoco are hollowed from the trunk of several trees: silverballi (*Nectandra*), karuhoho (Arawak), simaruba (Warrau) or muratatau (Carib); omu (Warrau); and sometimes of *Mauritia flexuosa* (Roth, 1924). Bundles of palm leaves (*Maximiliana maripa*) enter into the construction of the Oyana drums dug in the ground and struck with the feet.

Gums and Resins

Most of the gums known to the Indians are obtained from the Leguminosae. They are generally used as drugs, but may also be employed in the native industries.

Lighting Substances. All kinds of rubber burn quickly with a bright flame. In addition to its other industrial uses, rubber is collected in lumps of coagulated latex and carefully kept to light fires. The lump is drilled with the fire drill which produces a highly inflammable dust. The rosin of the locust tree ("jatoba", "jatahi", "simiri", "algarroba"—names which in different regions are given to the same or different species: *Hymenaea courbaril, Cassia blancheti,* and others) when lighted or thrown in a fire gives a brilliant light. Guaconax (*Amyris maritima*) and almecega (*Hedwigia balsamifera* and *Protium heptaphyllum,* the latter "the haiowa of the Arawak, shipu or sibu of the Warrau, and sipipio of the Carib" (Roth, 1924)) serve the same purpose.

Plastic Substances. On the upper Guaporé River the translucent rosin of *Hymenaea courbaril* and probably of many other trees is made into nose and lip plugs by means of wooden molds. The Guaraní used the rosin of a tree called "abati timbabỹ" in the same way. Several rosins are applied as a glaze to the whole or to parts of newly fired ceramics: in southern Brazil, Paraguay and northern Argentina the rosin of pau santo, palo santo (*Bulnesia sarmienti*); and in the north, that of icica (*Protium brasiliense, P. heptophyllum, P. guianense, P. aracouchili, P. carana*) and of *Hymenaea courbaril.* The Nambicuara make their pots waterproof by washing them when still hot with a decoction of the rosinous bark of a species

of *Mimosa*. The same is said of the Warrau (Roth, 1924).

Gums and Glues. The rosins already mentioned, especially those of balata or turara (*Mimusops globosa*) and of pau breo, manni, ohori or manil (*Moronobea coccinea*), are widely used for fastening points and feathers to arrows, for waxing threads, for calking canoes and for attaching stone chips or thorns on cassava graters, blades to knives and axes to their handles.

Balsams. The rosin of *Hymenaea courbaril* is chewed for pains in the stomach and flatulence, and is burned for fumigations in case of colds and headaches. The balsams of acouchi (*Protium* sp.), umiri (*Humiria floribunda*) and wallaba (*Eperua* sp.) are said to heal wounds. The same virtues are ascribed by Indians and Whites to *Copaifera multijuga*, *C. officinalis* and *C. langsdorfii*, which are known as "copayba", "cabima", "curucay", "curaki", "purukai", "mawna", "mararen" and "maran".

Corohiba or cabureiba (*Myroxylon toluiferum*, the tolu balsam of Colombia and Venezuela) is popular with the Indians of central and southern Brazil. According to Soares de Souza (1851), the ancient Tupinamba collected it with pads of cotton, which they later squeezed.

Other balsams used by the tropical Indians are cabreuva (*Myrocarpus frondosus*, *M. fastigatus*), obira (Apocynaceae), imbauba or ambay (*Cecropia adenopus*), corneiba (*Schinus terebinthifolius* or *Lithraea brasiliensis*) and gayac (*Guaiacum officinale*).

The Guayba, Tunebo and Chiricoa used a rosin called "mara" (*Protium* sp.) for hunting deer which are said to be attracted by its odor.

Oils and Unguents

To make oil of crab wood (caraba or andiroba, *Carapa guianensis*) "the Roucouyenne of Cayenne . . . preserve the seed for a year by burying it in the ground and making veritable silos of it . . . The Oyampi of the Oyapock River boil the seeds, expose them for several weeks to the air in a scooped-out tree trunk, crush them with their feet, and finally let them drip on an inclined palm leaf" (Roth, after Crévaux, 1924). The oil is used to anoint the hair and skin and to prepare paint. From makeima bark (*Mespilodaphne pretiosa* (Roth, 1924)) the Macushí extract an ethereal oil for use against diarrhea and dysentery. Most species of Lecythidaceae, some of *Eugenia* and *Virola*, and *Bertholletia excelsa* (Brazil nut) have fruits which, when boiled and crushed, yield an oil or a vegetable tallow which may be used as a food, as an unguent, or for lighting purposes. Palm oils are described under palms.

Pigments and Dyes

The most important pigment in all tropical South America is certainly the urucú or roucou (called "achiote" in México, "mantur" in Quechua, "bija" in the West Indies, and, in other dialects, "arnotta", "faroa", "kuseve", "shiraballi", "mubosimo" and "majepa"). *Bixa orellana* is cultivated by most tribes, although many of them merely transplant young wild plants to places near their huts. *Bixa orellana* is, however, a widespread wild plant and thus belongs to the large group of plants which have not been modified through cultivation. The red pigment of the urucú comes from a thin skin covering the seeds. These are washed and mashed, and the pigment, which settles to the bottom of the container, is dried, mixed with animal or vegetal oil or gum, and made into balls or cakes. Urucú dye is used to color cotton thread and to paint weapons, ceramics and implements, but it is employed especially to anoint the body and even the hair. Whether this widespread custom has a predominantly esthetic or hygienic function (protection of the body against heat

and insects) is a much-debated question. In northern Argentina, where cultivation of *Bixa orellana* is difficult, a decoction of pariah bark (*Simaruba, Simaba,* and *Pricrasma*), or palo amargo is used instead. Bodily ointments are also made from guavira (*Campomanesia*), taperihuá (*Cassia*), caburehi (*Myrocarpus*) and isipo kati (*Aristolochia*) (Pardal, 1937). Thevet (1878), Léry, Gomara and others have described the unguent used against body parasites and made of hiboucouhu; Hoehne considers this plant a form of *Myristica* (Hoehne, 1937).

Another red paint used for body and pottery decoration and varying from orange to purple, according to the technique of preparation, is caraweru, barisa, barahisa, biauro, etc., which comes from the boiled or fermented leaves of *Bignonia chica.* It is kept in small straw baskets or in tubes. Unripe *Genipa* fruit of the jagua or xagua, launa or lana, tapuriba, tabuseba, etc. (*Genipa americana*) yields a juice which becomes black or dark blue when exposed to the air. From Argentina to the Guianas it is used as a dye and as a paint for the body and for pottery and utensils. The tree is sometimes cultivated. From arrisaura or karasaru berries the natives of the Guianas extract a clear blue used for body paint.

The following dyes are used more for native handicrafts than for the body: pau brasil of the old travelers or oroboutan of the Tupinamba (*Caesalpina echinata*), used to dye feathers red; other red dyes are yzipo roots, mentioned by Dobrizhoffer (1822), mespil or itarra (*Bellucia aubletii*) used in the Guianas to paint the paddles, the inside of calabashes, etc., maba bunakara (*Coussapoa latifolia*) and buri-badda (*Homalium ?*), *Maparakuni erythroxylum* of the northeastern Arawak, and kuruwatti (*Renealmia exaltata*) used as a remedy for ophthalmia, as a dye and on the Pomeroon, supposedly as the pigment for tattooing in the old days (Roth, 1924).

Besides *Genipa americana,* a black dye is extracted from inga or shirada bark (*Inga lateriflora*). It is used mostly in basketry. Several yellow pigments come from tatajiba or tayuva (*Chlorophora tinctoria*) which has an edible fruit, and from an unidentified plant which Soares de Souza called " caapiam " (Hoehne, 1937). A blue indigolike dye comes from *Anil trepador* (*Vitis sicyoides*) and from anil-assi (*Eupatorium* sp.). The old literature mentions several other vegetable dyes which are not yet identified. The sakuapéra of the Arawak and Warrau is *Henrietta succosa* (Roth, 1924).

Shampoos

Shampoos include the Brazilian arvore de sabão; this is the Guiana and West Indian I of the Taino, identified by Roumain (1942) as *Gouania lupuloides* or *G. polygama;* certain roots and fruits of *Sapindus divaricatus* used by the Tupí, ejaru (*Colletia spinosa*) of Bolivia, Chile, Uruguay and Argentina, and *Sapindus saponaria* of Venezuela, Brazil and Argentina.

Rubber

According to Roth (1924), *Sapium jenmani,* or *S. cladogyne,* and some species of *Hevea* were probably the original sources of rubber. The Omagua made balls, rings, and syringes from the milky sap of a creeper which, from the structure of its fruits and flowers, must be ascribed to a genus of the Apocynaceae.

The rubber balls of the Paressi and Nambicuara are made of the latex of mangabeira (*Hancornia speciosa*). The name " caucho " (rubber) is given to *Castilla elastica* and to *Sapium eglandulosum.* The rubber latex of soveira or sorveira (*Couma guianensis, C. macrocarpa, C. utilis*) can be drunk either pure or diluted with water. The Indians coat their skin with the latex of several rubber trees in order to suffocate parasite worms lodged under the epidermis.

Foods

Tubers. Wild food plants include roots, fruits, nuts and shells. Few tubers have been identified because the Indians generally collect them only in time of scarcity as substitutes for manioc, *Dioscorea, Zanthosoma* and other cultivated tubers. Among the wild tubers eaten is mandioquinha do campo (*Zeyheria* sp.).

Green Vegetables. Green vegetables are scarce in native diet, being limited to manioc leaves, palm shoots, a species of *Cissus* which Nimuendajú found cultivated among the eastern Ge, and very few others.

Nuts and Seeds. Besides palm nuts, which are consumed from the Chaco to the Guianas, there are two other nuts of great value. The Caingang and Guaraní of southern Brazil depend for several months each year on the nuts of *Araucaria angustifolia*. The Tupí called these " iba ", the fruit " par excellence." To the Araucanians they are just as important. In the Amazon Basin, sapucaia (*Lecythis ollaria* or *L. pisonis*) and Brazil nuts, tocari (*Bertholletia excelsa*), are not negligible items of native diet. These nuts were a favorite food among many tribes of the Beni and the Madre de Dios Rivers.

Other nuts with food value for the Indians are those of piqui (Almendras del Brasil), sawari or chachapoya (*Caryocar barbinerve, C. brasiliense, C. tuberculosum, C. amygdaliforme*), comanda-iba (*Sophora tomentosa*), comanda-assu (*Mucuna altissima*) and jatoba or locust tree (*Hymenaea courbaril*).

In the Guianas, cassava flour is often increased, mixed with, or even replaced by flour made of the following seeds: mora (*Dimorphandra mora*), greenheart (*Nectandra rodiaei*), dakamballi (*Vouacapoua americana*), pario, and nuts of the sawari tree (*Caryocar tuberculosum*). Roth (1924) quotes Schomburgk on the occurrence of wild maize (?) on the eastern foot of the Pacaraima Range. Not only seeds and nuts are occasionally added to cassava flour, but also soft wood.

Wild rice (*Oryza subulata*) is abundant in Uruguay, Rio Grande do Sul, in the marshes of the upper Paraguay and of the Guaporé Rivers (Hoehne, 1937) and in the Orinoco Valley, but the Indians of the last region do not seem to have consumed it. According to Hoehne, *Oryza sativa* may be aboriginal in South America.

Although peanuts (*Arachis hypogaea, A. nambyquarae*) were generally cultivated, " southern Brazil, and particularly São Paulo, Paraná, and Mato Grosso, is the land of origin of the different peanuts. All known species still exist there in wild state . . ." (Hoehne, 1937).

Fruits. Some widely distributed fruits were used both cultivated and wild: caraguatá (*Bromelia fastuosa*); inga, shirada or pacay (*Inga vera, I. lateriflora, I. bahiensis, I. fevillei*); maracuja (*Passiflora quadrangularis, P. alata, P. edulis*); and pineapple (*Ananas sativus*). Use of the following centers around the Chaco, southern Brazil, southern Bolivia and northern Argentina: the important algarroba or aloja (*Prosopis alba*), principally used as a drink; guabiroba (*Myrtus mucronata* and *Psidium multiflorum, P. corymbosum, P. cinereum, P. guazumaefolium*); guavira (*Campomanesia*); tamarin, common in the Chiquitos region but lacking in Paraguay, according to Dobrizhoffer; tusca (*Acacia aroma*); taruma (*Vitex montevidensis*); and chañar (*Gourliaea decorticans*). A curious use of quebracho, wood yielding tannin, may be mentioned here: " The Guaraní burn pieces of the tree tayȳ, receive the smoke or soot arising from them into a clean dish, and by pouring hot water upon it, convert it into ink which mixed with gum and sugar is by no means to be despised ". (Dobrizhoffer, 1822).

The fructa do lobo (*Solanum grandiflorum*, yielding the alcaloid, grandiflo-

rina) has a central and southern distribution in the savanna lands of central Brazil. Its delicious large peach-like fruit seems to be the object of a food prohibition in several regions. Some varieties may be toxic.

Cashew (*Anacardium occidentale*) is generally cultivated, but another wild species, *Anacardium giganteum*, yields small fruits which the Indians collect at the foot of the tree after the monkeys have thrown them down. The Brazilian Indians consume the fruits of several other species of Anacardiaceae: umbú (*Spondias tuberosa*), hobo, jobo (*Spondias monbim, S. dulcis, S. robe*), cajamirim, maropi or hog-plum (*Spondias lutea*) and acaju or acaja (*Spondias monbim*). The tuber-like roots of umbú are edible.

Mangaba fruits (*Hancornia speciosa*) are so important to the savanna tribes that when they are in season the Indians undertake large expeditions for the sole purpose of collecting them. Likewise of great importance are the fruits of *Psidium turbiniflorum, P. guayava, P. variabile* and of several Myrtaceae, such as cambuy and jaboticaba (*Mouriria pusa*), both common trees in eastern Brazil.

The following species yield fruits which are eaten occasionally by the Indians: cambuca (*Myrcia* sp.), massaranduva or macarandiba (*Lucuma procera*), mucugé (*Couma rigida*), ubauba (*Pourouma cecropiaefolia*), ubacaba (*Britoa triflora*), murici (*Byrsonima*), canapu (*Physalis pubescens*), *Cereus* sp., *Eugenia* sp., *Genipa maerianae* and *G. edulis*, *Malpighia* sp., banana do brejo (*Monstera deliciosa*), etc.

In the northern part of the continent and in the Antilles, fruits eaten include the following: oiti coro (*Couepia rufa*), oiti da Bahia (*Moquilea salzmannii*), piquia (*Macoubea guianensis*), bacopary (*Rheedia brasiliensis*), icaco (*Chrysobalanus icaco*), bacury (also cultivated) (*Platonia insignis*), abio (*Lucuma caimito* and *Pouteria caimito*, which are different from the caimite of the West Indies, *Chrysophyllum caimito*), the mammee apple or abrico do Para (*Mammea americana*, to be distinguished from the mamey of Cuba, *Calocarpum mammosum*), several species of *Couma*, several Annonaceae (*Annona muricata, A. reticulata*, aratiçu) and several species of cacao (*Theobroma cacao, T. bicolor, T. grandiflorum, T. speciosum*). The wild kakaui (*Theobroma sylvestre*) and the cacau selvagem (*Pachira insignis*), which are eaten raw, are important food items for the tribes of the upper Madeira River.

Some kinds of mushrooms were consumed on the Orinoco, and are also considered a delicacy by the Nambicuara.

Drinks

When no water is available, the Indians know how to quench their thirst with the sap of several vines and creepers. This sap resembles pure clear water and it can be gathered easily in a calabash. The best known are waterwhithe (*Vitis* sp., *Entata polystachya*) and salisali (*Lonchocarpus rufescens* or *Lonchocarpus nicou*), a creeper also used for drugging fish. Its water is clear and fresh, but only its first flow can be drunk because later it becomes white and milky, and is toxic (Crévaux, 1883).

In periods of drought the Arawak of Pomeroon obtained water from truli fruits (*Manicaria saccifera*). Water may also be obtained from the sheath bases of the leaves of *Tillandsia*, burití palm (*Mauritia flexuosa*) and caraguatá (*Bromelia* sp.).

A great many beverages, some of them fermented, are prepared from the fruits, seeds and roots of wild plants. A popular liquor is made with the cultivated and wild pineapples (*Ananas sativus*). The ancient Tupinamba prepared a fermented beverage with cashews (*Anacar-*

dium occidentale). In the Chaco beer is made with chañar (*Gourliaea decorticans*), mistol (*Zizyphus mistol*), tusca, algarroba pods (*Prosopis*), etc.

Refreshing drinks are obtained from hitchia (*Byrsonima spicata*), hlawaraballi (*Protium heptaphyllum*), guavira (*Campomanesia*) and several species of *Psidium* and *Eugenia*.

Condiments

The preparation of salt from the ashes of leaves or fibers of some palm trees has been described. Another type of vegetable salt is obtained by boiling an aquatic plant, oulin, weya, weira, weyra or huya (*Mourera fluviatilis*). It is dirty brown and inferior in quality. Roth, who describes its preparation among the Guiana Indians, considers it the same as the caruru salt mentioned by Coudreau (Roth, 1924), and it is probably the same as the Trumai salt made from waterlilies (Quain, ms.). Numerous tribes, for instance the Nambicuara, cannot bear the taste of salt, but tribes which do enjoy it use native salt, bitter as it is, in large quantities. There is, in fact, a strong contrast in the like and dislike of various tribes for " hot " foods.

Peppers (*Capsicum*) are usually cultivated, but wild peppers (*Capsicum rabenii, C. baccatum*) occur on the Brazil coast (Soares de Souza, quoted by Hoehne, 1937). The coastal Tupí used a " long pepper which is crushed together with salt, pinches of which are swallowed after each mouthful "; this may be *Piper longum* or the bitter grass jambi or nhamby (*Eryngium foetidum*) which was also known to be used as a condiment (Hoehne, 1937). Jambi has also been identified as *Ageratum conyzoides*.

The Nambicuara flavor tonka beans, known in Brazil as " cumaru " (*Dipteryx odorata*), by crushing handfuls of them with grasshoppers. The Tupí-Cawahíb add tocari (Brazil nut, *Bertholletia excelsa*) to maize when preparing maize beer (Lévi-Strauss, ms.).

There are other condiments of animal or mineral origin.

Poisons

The composition of curare has been the object of many discussions. Sampaio (1916) lists the following plants which are used in the preparation of the curare of the Nambicuara and Paressí: *Strychnos* sp., *Lisianthus virgatus, Cassia rugosa, Dioscorea* sp., and species of Apocynaceae, Marcgraviaceae and Sapindaceae. Vellard (1939), however, has proved that the Nambicuara curare consists only of the extract of a plant of the genus *Strychnos*. There is no doubt that this and other species of *Strychnos* (*S. medeola, S. toxifera, S. cogens, S. crevauxi*) provide the active element in the preparation of the more elaborate poison of the Amazon Basin.

Dance, quoted by W. E. Roth (1924), makes mention of two other arrow poisons: heauru-canali and hurubuh, similar to hog tannia.

Bresillet or carasco (guao of the Taino) was perhaps used as an arrow poison, and Oviedo mentions it as a cosmetic for whitening the skin (Roumain, 1942). It is doubtful that the poisonous manceniller (*Hippomane mancinella*) was ever used for arrow poison. A poisonous bamboo used in the Guianas as an arrow point is said to be *Guadua latifolia* (Roth, 1924). Roth quotes Barrère that arrows were poisoned in Cayenne with the milk of the pougouly tree (*Ficus venenata*) and with several other ingredients.

Among other poisons were *Thevetia ahouai* (eastern Brazil), *T. peruviana* (northern Brazil and West Indies) and *T. bicornuta* (Mato Grosso), commonly known in Brazil as " Chapeu de Napoleão ", which Thevet (1878) stated were used for revenge in love affairs. The Nambicuara used the rosin of certain

Bombacaceae as a magical poison, and there are many other unidentified native poisons, such as pakurú-neará, a cardiac poison of the Chocó mentioned but not identified by Nordenskiöld (1930) and studied by Santesson (1929). In Surinam there was an especially poisonous arum called " punkin ", *Arum venenatum surinamense* (Roth, 1924). Most poisons are kept secret by the natives.

Several wild grasses are known as poisonous to animals.

The so-called fishing poisons include a large number of plants, the physiological actions of which are not at all identical. Some are true poisons, some act only by suffocating the fish.

Hoehne (1937) lists for Brazil three groups of fish poisons: guarana timbo (*Dahlstedtia pinnata*); many species of *Tephrosia*, in particular *T. toxicaria;* and the group of the timbo do cerrado, comprising *Magonia pubescens, Indigofera lespedezoides* and a species of Sapindaceae.

The *Tephrosia* species are known under the name of " tingui " in most parts of Brazil and as " yarro-conalli " by the Macushí. The barbasco of eastern Bolivia and the upper Amazon is *Serjania perulacea.* In Perú the name " barbasco " is also given to *Tephrosia toxicaria.* The ochoho of eastern Bolivia is *Hura crepitans.*

In the Guianas the following fish poisons were identified: *Tephrosia;* haiari, heri, nako (kumu or cube of Perú) (*Lonchocarpus nicou, L. densiflorus, L. rufescens*); quanami, gonami, kunalli, etc. (*Clibadium asperum, C. surinamense*). On the Demerara, cumapuru (*Phyllanthus conami*) leaves are bruised with leaves of kunami, a shrub, and the dried light pericarp of the arisauru (*Derris pterocarpas*), which give buoyancy to the mass, and cast into the river along with pellets of dough to tempt the fish and to paralyze and kill them (Roth, 1924). Haiara-balli (*Muellera frutescans*) is an Arawak poison. According to Gumilla, alligators were shot with arrows made of poison bamboo (Roth, 1924).

There are several antidotes for poison, among them a decoction of *Potalia amara* leaves for cassava poisoning, the only one identified by Roth.

Medicines

Early travelers were surprised at the number of herbs known to the Indians and by the fact that the natives always used " simple " remedies, each employing only one plant at a time, whereas Europeans relied more on semimagical combinations of several herbs.

Few primitive people have acquired as complete a knowledge of the physical and chemical properties of their botanical environment as the South American Indian. With the exception perhaps of cinchona bark, especially cascarilla of the Spaniards (*Cinchona pubescens*), there is no species used in modern pharmacopoeia which was not familiar to the natives in pre-Columbian days. Furthermore, it is probable that only a fraction of the herbs used by modern Indians are presently known and exploited. The following list is only partial and fragmentary, and it is limited to the species mentioned most frequently in the literature.

For most internal disorders, the natives administer an emetic followed by a purgative. The principal emetic is the root of ipecac or poaia (*Cephaelis ipecacuanha*), but in certain regions of the Guianas, the Indians use the bark of the wallaba tree (*Eperua* sp.), a small creeper (*Vandellia* sp.) and tobacco juice (Roth, 1924). Other emetics known to the Indians in central Brazil are *Cissampelos glaberrima, Manettia ignita,* the kaamarã tai (*Asclepias curassavica*) and kaa' chsa (*Chiococca anguifuga*).

A great many purgatives are known to the Indians: several species of *Caya-*

ponia (tayuya of the Tupí); cassia (taracu, *Cassia occidentalis*); several kinds of nuts, such as anda-uassu (*Johannesia princeps*) and pinhão do Uruguay (*Jatropha curcas*); jeticucu or batata da purga (*Operculina convolvulus*); several species of *Ipomoea;* sarsaparilla (*Herreria salsaparilha*) and its numerous substitutes (*Smilax aspera*). Against worms the Indians use gameleira branca, the latex of *Ficus anthelmintica* or *F. glabrata, F. dolaria* and of some other Moraceae, the seeds of *Andira,* etc.

For gastric disturbances, the Brazilian Indians take paico (*Chenopodium*) and *Dryopteris;* the Guiana Indians, *Jatropha gossypifolium, Boerhaavia hirsuta, Chelonanthus alatus, Allamanda aubletti;* and the marginal Indians of the tropical forest area, yerba del moro (*Amaranthus* sp.) or urutu (*Alternanthera repens*).

For healing wounds, the Brazilian Indians used, besides balsams (q. v.), the crushed seeds of *Mucuna altissima,* tupixaba (*Scoparia dulcis*), hiboucouhu (*Virola* sp.), crushed seeds of the toxic fruits of *Carapa guianensis,* pounded and parched leaves of *Piper jaborandi,* and *Pilocarpus pennatifolius.*

Astringent herbs of native pharmacopoeia are camara (*Lantana camara*), *Polypodium crassifolium, Oxalis tuberosa* and *O. angustifolium.*

To stop bleeding the Indians used *Arenaria lanuginosa, Oenothera rosea, Chrysophyllum glycyphloeum* and some mushrooms (*Polyporus coccineus* and *Geaster saccatus*).

Among the drugs used to cure eye pains, a constant complaint of South American Indians, Roth mentions red-pepper juice, the leaves of mokumoku (*Caladium arborescens*), a decoction of wansimai roots, and the purplish red juice of kuruwatii (*Renealmia exaltata*). A plant " similar to a palm tree " (*Jatropha urens,* according to Hoehne) serves the same purpose.

Febrifuges include decoctions of the barks of *Diospyros paralea, Scoparia dulcis, Lisianthus purpurascens, Tachia guianensis, Strychnos pseudo-quina, Cassia amara,* amapaima or casca preciosa (*Cryptocarya pretiosa*), *Uvaria febrifuga* and *Nectandra rodiaei,* and infusions of *Eryngium foetidum, Byrsonima crasifolia* and guarana (*Paullinia sorbilis*). Other febrifuges listed in the literature are quina (*Hortia brasiliana*), quinaquina (*Myroxylon* sp.), quina do matto (*Esenbeckia febrifuga*), taperihuá (*Cassia* sp.), coroba (*Jacaranda oxyphylla*), caapeva (*Pothomorphe sidaefolia*), caapomonga (*Plumbago scandens*) and camara (*Lantana* sp.).

Against diarrhea and dysentery the Indians made infusions of the bark of *Byrsonima crassifolia, Ambelania acida, Jatropha curcas, Stachytarpheta jamaicensis, Cephelis ipecahuanha* and *Acrodiclidum camara* or Akawai nutmeg, and of the seeds of greenheart (*Nectandra*); also of the sap of the wild nutmeg as a mouth wash and a cure for yaws (Roth, 1924).

Antidotes used in Guiana for snake and spider bites, sting-ray wounds and poisonous arrows are: *Dracontium dubium, Byrsonima crassifolia Rhizophora mangle* and *Potalia amara* (Roth, 1924). The Yahapé used *Kyllinga odorata* and caapia (*Dorstenia* sp.).

Sedatives known in Brazil include guaxima (*Urena lobata*) and ubirataya or ibirarta-iba (*Pilocarpus pennatifolius*). Abutua (*Chondrodendron platyphyllum*) and *Verbena erinoides* are appetizers. To cure venereal diseases the Indians used the bark of hyvourahi (*Pradosia glyciphloea,* according to Hoehne) and several species of Bignoniaceae.

Other plant uses are: aphrodisiacs (*Justicia pectoralis* and *Jatropha* sp.), contraceptive (*Stenomesson variagatum*), cure of toothache (mohomoho or jaborandiba, *Piper* spp.), hernia remedy (samambaia, *Pteridium aquilinum*), and

cure of pulmonary afflictions (*Gnaphalium spicatum*), blisters (*Ranunculus pilosus*), scurvy (*Nasturtium pumilum* and *N. officinale*), hemorrhoids (*Tillandsia usneoides*) and catarrh (*Mirabilis peruviana*).

Several species of *Datura* and *Thevetia* are used for their anesthetic properties.

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Utilization Abstracts

Creosote Bush. The creosote bush (*Larrea divaricata*), erroneously known also as "greasewood", is the dominant drought-resisting plant of the American Southwest and the northern Mexican deserts where it covers, often in almost pure stands, an estimated 35 million acres from west Texas to California and from Nevada to north central Mexico. It occurs also in the arid regions of Argentina and Chile. As a result of phytochemical studies initiated about a decade ago at the University of Minnesota as part of the Indian Medicinal Plants Project of the U. S. Department of Agriculture, a number of compounds were isolated from this shrub, one of which, a phenolic constituent—nordihydroguaiaretic acid or N.D.G.A.—has attained commercial importance as an anti-oxidant. Extraction mills for obtaining this substance are located in Presidio, Texas, and Torreon, Mexico; final processing is carried out in Chicago, Illinois. Extractable resins and cattle feed are possible other products to be derived from these otherwise useless plants of the desert. (P. C. Duisberg, *Chemurgic Digest 10(10): 6. 1951*).

Coconut Chips. This new hors d'oeuvre, consisting of somewhat curved and wrinkled, tan to white, ribbons of coconut meat is acquiring increasing popularity in Hawaii. Manufacture of the crisply roasted and salted delicacies began as a kitchen enterprise of two young ladies in 1947 but did not attract public attention until their appearance at the famous Royal Hawaiian Hotel at Waikiki when it reopened after years of war duty as a navy recreation center. With outside financial assistance, the two originators thereafter became incorporated as Polynesian Food Specialties, and today in new quarters are processing about 2,000 coconuts per day. Byproducts of this new Hawaiian industry are the husks for gas masks and the shells for making buttons. (Letter from Otto Degener, Oahu, Hawaii).

Waxes. Nearly 20 million pounds of carnauba wax, obtained from the leaves of palm trees in Brazil, are imported every year into the U. S. Perhaps the next most important commercial wax is candelilla, about four million pounds of which come every year from plants in Mexico. Six million pounds of other waxes are also imported annually. Potentially but as yet unexploited domestic sources include sugar cane, sorghum, Douglas fir bark and jojoba bean. (J. V. Steinle, *Chemurgic Digest 11(6): 4. 1952*).

Breeding and Establishing New Trees Resistant to Disease

While the vanished American chestnut has not yet been replaced by blight-resistant chestnuts, or white pines, elms and poplars saved from the ravages of other diseases, great advances have been made toward achieving these goals.

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Introduction

Epidemic tree diseases resulting from the introduction of fungus parasites into this country have caused losses beyond calculation to our forest and shade trees. The chestnut blight destroyed the American chestnut throughout its range in the eastern United States. Federal expenditures to control white-pine blister rust amounted to over $58,000,000 in the period 1915–1950; control work is continuing at a heavy cost. Damage to American elms by the Dutch elm disease amounts to millions of dollars, exclusive of large sums being spent for control work. Intensive direct control measures for forest-tree diseases are generally impracticable (Hartley, 1950); at their best they serve to check the progress of a disease and to reduce damage. Control measures for shade-tree diseases are limited in scope by the small number under a single management (Hartley, 1950). In time the number of our forest and shade tree species could be alarmingly reduced by introduced diseases and by endemic diseases that suddenly shift to epidemic nature (May, 1947; Stakman, 1947) unless counteraction based on fundamental principles is taken. Such counteraction lies in prevention of further disease introductions and in early establishment of projects for the breeding of new races or of hybrids that are resistant to epidemic diseases.

There can be little doubt that the cost-benefit ratio has been exceedingly favorable in the breeding of crops such as corn and other cereals and vegetables for increased production and for resistance to pests and diseases. The cost-benefit ratio in tree-breeding may not appear so favorable because of the comparatively longer time required by trees to mature their crops. However, we must not be cowed by time. We must accept as fact that breeding trees for increased production and for resistance to pests and diseases can be as profitable, if not immediately to our generation, then to future generations. A crop ruined in the seedling stage can often be replaced at relatively slight cost, but a plantation a generation old destroyed by parasites is a more serious loss. "Resistance breeding" insures the safety of an investment which has already been made (Frankel, 1950).

In 1909 the chestnut blight offered the first incentive in this country to breed trees resistant to a disease (Van Fleet, 1914). In 1924 poplar breeding was undertaken for the production of fast-growing disease-resistant trees (Stout et al., 1927). The breeding of elms resist-

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ant to the Dutch elm disease, and to phloem necrosis, a virus disease of unknown origin, began in **1937** (Walter, May and Collins, **1943**; Smucker, **1944**). About this time steps were taken to select white pines resistant to the blister rust (Hirt, **1948**; Riker et al., **1943**). Selections of the ornamental mimosa for resistance to the mimosa wilt were made in **1939** (Hepting and Toole, **1942**). These outstanding breeding projects are designed to counteract diseases of epidemic proportions which threaten the existence of some of our major species of forest and shade trees.

There are numerous endemic diseases now attacking forest and shade trees and doing a limited amount of damage to them each year, but under good management, losses from such diseases can be largely prevented (Wyckoff et al., **1947**; Hepting, **1940**).

This review deals with the principles and practices of breeding and establishing new forms of forest and shade trees resistant to disease, and with the progress of breeding and establishing new forms of forest and shade trees resistant to specific epidemic diseases in North America.

The principles and methods of breeding trees and other plants have been outlined or discussed by numerous workers. The following references were selected for their treatment of special principles and other information applicable to the breeding of trees: Blakeslee, **1945**; Briggs, **1938**; Brink, **1949**; Champion, **1945**; Dorman, **1950**; Duffield, **1942**, **1950**; Duffield and Stockwell, **1949**; Graves, **1948**; Hayes and Immer, **1942**; Hudson, **1937**; Hutchinson, **1940**; Hutchinson et al., **1937**; Johnson, **1939*a***, **1939*b***; Lindquist, **1948**; Mirov, **1940**; Patel, **1938**; Pauley, **1949**; Pearson, **1944**; Richens, **1945**; Righter, **1946**; Schreiner, **1937**, **1938**, **1939*b***, **1950**; Smith and Nichols, **1941**; Snow and Duffield, **1940**; Stebbins, **1949**; Stockwell and Righter, **1943–1947**; Stoeckler, **1950**; Syrach-Larsen, **1947**.

Information applicable to the breeding of trees for resistance to disease may be found in the following references: Aamodt, **1934**; Briggs, **1942**; Clapper and Miller, **1949**; Graves, **1938**, **1948**; Hayes, **1930**; Kostoff, **1934**; Reddick, **1943**; Richens, **1945**; Riker, **1945**; Salaman, **1936**; Walker, **1941**; Wenholz, **1934**.

Some of the above mentioned literature applies to the breeding of agricultural crops, but much of it is also pertinent to the breeding of trees. Trees differ in some respects from short-rotation crop plants when breeding for resistance to disease. Short-rotation crop-plants require a high degree of genetic uniformity for the production of high grade crops, and this uniformity increases the risk of damage from epidemic diseases. If the grower loses his annual crop from disease, he may replant next year with a more disease-resistant plant or with a different type of crop plant.

An epidemic disease may practically destroy a stand of trees which required decades to reach economic usefulness, with the result that the area is left to reseed by chance, or it must be replanted with other tree species which again require long periods to mature. On the other hand, the longevity of trees and the fact that most of them can be propagated vegetatively are advantageous to the tree breeder. A single disease-resistant selection can be used to make numerous crosses from year to year; the selection and the genotype which it represents can be increased by vegetative propagation and be preserved either for further breeding or for growing in plantations.

In contrast to the genetic uniformity required in agricultural crop-plants, the heterozygosity inherent in seedling trees generally tends to reduce the incidence of and the damage done by pathogenic parasites. An exception, however, is the

American chestnut which was destroyed in less than a half century by an introduced bark-killing fungus.

Resistance may be defined as the ability of an organism to oppose the operation or to lessen or overcome the effects of an injurious pathogenic organism or virus (Reddick et al., 1940). Degrees of resistance may be considered as extending from zero resistance or complete susceptibility to complete immunity. The plant breeder must determine and obtain that degree of resistance to a disease in his selections which will permit them to grow healthily at least throughout their rotation periods in suitable habitats and with proper management. Breeding for a high degree of resistance to disease may not always be necessary. Some plants tolerate disease and suffer no appreciable injury.

Selecting and Testing for Resistance to Disease

Selecting for resistance to a particular disease may begin within the species which is attacked. This species is already established ecologically, and a few truly resistant individuals, if found, may be used as parental material in the development of a pre-adapted resistant race. If selection within this species is not fruitful of improvement, the search for disease resistance may be extended to related native species. The ecological requirements of such species, however, may be significantly different from those of the disease-susceptible species. This barrier to adaptation of a related species to the habitat of the susceptible species may be overcome by methods of hybridization (Patel, 1938; Went, 1950).

In the search for disease-resistant individuals, true resistance must be distinguished from apparent resistance that is due to escape from infection, to juvenile growth which may not be readily attacked or to certain environmental influences which may not favor attack by the pathogen. Kelley (1948), for instance, found that American chestnut seedlings growing in the shade appeared unaffected by the blight, while those in full sunlight were mostly affected.

Seed and cuttings are collected from a number of individuals showing apparent resistance and also from some susceptible trees. Seed are sown and the cuttings grafted, and at an appropriate time they are inoculated with the pathogen so that their true resistance may be determined. If the disease is one that attacks nursery seedlings, the inoculations are made on young plants, otherwise the selected plants should reach a suitable age for inoculation. Collection of both seed and scions or cuttings from selected mother trees is desirable, since the seedlings may reveal, early in the work, some indication of the mode of inheritance of disease resistance, and the clonal propagants, after inoculation, will show which mother trees are resistant.

Inoculating Selections. The technique of inoculating host plants with a pathogenic organism or virus should follow generally the methods and locations of natural infections of the host. For example, the pitch canker fungus (*Fusarium lateritium* f. *pini*) usually attacks and kills the leaders and branch terminals of turpentine pines, but when inoculated into the trunks it merely stimulates the flow of resin and kills only small amounts of tissue. Hence, a test for resistance to this pathogen would be made by inoculating leaders and branch terminals rather than the trunks of these pines. Some virus diseases of plants are transmitted solely by insects that carry the virus, and artificial methods of transmitting these diseases fail.

Inoculation tests to reveal resistant individuals must be severe (Walker, 1941; Reddick, 1943), though the objective may be an end product only moderately resistant or tolerant to the disease. Breeding trees is an expensive operation

and the breeder cannot afford to assume disease resistance in his selections.

The selection process should extend to the disease organism for the purpose of obtaining the most virulent form. Where the pathogen is advancing through the range of its host, it is sufficient to obtain cultures in areas where host plants are newly infected. If the entire range of the host has been traversed by the disease, cultures of the organism should be obtained from widely separated areas for inoculation of a uniform lot—preferably a clone—of host plants to determine which culture is the most virulent.

Walker (1941), Wingard (1941) and others (Aamodt, 1934; Brown, 1936; Butler, 1936; Dickson, 1934; Hayes, 1930) have discussed the nature of disease resistance, variability of disease organisms and the relations of environment to disease resistance. Familiarity with these topics is helpful in the early work of selection for resistance as well as in the final stages of establishing new disease-resistant trees in suitable habitats.

Introduction of Related Disease-Resistant Species. No program of breeding trees resistant to disease is complete until investigation is made of related foreign species. Boyce (1941) surveyed the possibilities of using exotic trees directly as forest components. The possibilities appear not too promising when exotics are introduced to new climatological, edaphic and biotic conditions. However, when an exotic species is resistant to an epidemic disease—this is usually known in advance—the introduction of all available races or varieties of the species for test purposes is certainly justified. To save time on an extensive project of this kind, tests for adaptability, crossability with the native species and disease resistance should run concurrently.

Tests for adaptability and disease resistance can be aided by studies made by the plant explorer (Bruman, 1938). A knowledge of phenology (Gevorkiantz and Roe, 1935; Huberman, 1941) or bioclimatics (Hopkins, 1938) is essential to the proper distribution of an introduced species of plant. The technique of agroclimatic analogues (homoclimes) is described by Hanson (1949) and has been applied in the establishment of exotic tree species (De Beuzeville, 1943; Prescott and Lane-Poole, 1946). Nuttonson published the agro-climatic analogues in North America with resect to the agricultural climatology of Japan (1949), and to that of Siberia (1950). For immediate use, however, the tree breeder requires seed, scions and pollen of the disease-resistant exotic species. These plant materials, respectively, provide him with sources of variation within the species, clones of races or varieties within the species, and means for conducting crossability tests without waiting for seedlings or grafts to bloom.

The introduced species may have one or more important uses other than possible hybridization with the native species. An introduction of the Chinese chestnut, after nearly one quarter of a century of testing for adaptability and resistance to blight, shows promise as a blight-resistant forest tree (Diller, 1940, 1946). This species is already established in some areas as profitable orchard trees (Reed, 1947; Ulm, 1948*b*), and considerable searching among experimental plantings has yielded three named selections producing excellent nuts (McKay, 1950; Reed, 1950). These forest and orchard plantings, made throughout the eastern half of the United States, will always provide sources of material for further selection and breeding for a variety of characteristics.

Hybridizing for Resistance to Disease

The mechanical work of crossing is eased by using flowering selections in the progeny rows, in test plantations or in

the disease test garden where the inoculations are made. Resistant selections scion-grafted on the tops of old trees of the same or related species frequently produce flowers within a few years. Susceptible selections may be treated similarly with the probability that some years of flowering will be obtained before disease kills the grafts. Disease-resistant trees are crossed with other resistant trees to determine whether any individuals of the first or second generation show a more extreme development of resistance than the resistant parent showed. Resistant trees are also crossed with susceptible trees to determine whether resistance is inherited as a dominant, incompletely dominant or recessive character, and to incorporate desirable characteristics of both trees in the hybrid. Crossing within a species usually offers few genetical difficulties. Closely related species also usually cross readily, and in some instances the F_1 hybrids may show hybrid vigor. This characteristic is highly desired in tree hybrids, whether or not disease resistance is an objective in the breeding project. Forest-tree species usually are uniform to the extent of reproducing true, even though they are normally cross-fertilized, and the first generation from crossing such species, if they are compatible, will be fairly uniform in taxonomic characters. The F_1 trees may or may not react uniformly to attacks by the pathogen, especially since varying environmental conditions can alter the course of the disease on individual trees.

Crossing distantly related species sometimes is unsuccessful because of some form of sterility. Species of one genus differing in their chromosome numbers usually cross with difficulty. In such cases many pollinations may yield but a few seed from which to grow F_1 plants. These plants may be intercrossed to obtain a large number of second-generation trees for observation. If they do not intercross readily, then backcrossing to one of the parent trees should be more successful. Lewis (**1949**) described the types of incompatibility and its genetics in flowering plants.

A large number of second-generation individuals is desirable in any tree-breeding project. The first generation reveals which characters are dominant, intermediate or recessive, but the second generation is essential for determination of the ratios in which these characteristics are inherited. The second generation, sometimes called the segregating generation, may reveal a few individuals with a greater degree of disease resistance than that shown by the resistant parent. A large second generation is also desirable when susceptibility to a disease appears as a dominant trait in the F_1 trees. The ratio of resistant individuals in the second generation with this type of inheritance will be small, and they might not appear in a small population. Second-generation trees are obtained by selfing the F_1 trees, if possible, otherwise by intercrossing the F_1 trees. To obtain a fairly typical second generation by intercrossing, each F_1 tree is crossed with every other F_1 tree.

Much land space is required to grow large numbers of second-generation trees, and it is not wise to restrict the use of suitable land for this purpose. If possible, the early production of hybrids should be on good soil and within easy access to the breeder and pathologist who must continually work with the hybrids and assess their value. Where such land is not available, the new trees may be interplanted with commonly used stock wherever suitable land is available (Righter, **1946**).

Production of Backcross-Generation Hybrids. The backcross was used primarily for the study of linkage of characters, but in recent years it has become more and more important as a system of mating for the development of disease

resistance and other characteristics (Briggs, 1938, 1942; Hudson, 1937; Hutchinson, 1940; Hutchinson et al., 1937; Patel, 1938). First-generation hybrids or selections from the second generation may not possess sufficient resistance to disease, or they may not express one or more other characteristics desired in the end product. In such cases the hybrids are backcrossed to the parent tree that expresses the desired character. A disease-resistant parent tree, if an exotic, may not have other desirable characters possessed only by the native species. Backcrossing the hybrid to the susceptible native species may transfer one or more of these desirable characters to the progeny along with greater susceptibility to the disease. Another backcross, this time to the resistant parent, with selection from the progeny, may yield individuals that express the desired resistance and other characteristics.

Backcrossing or parent-offspring crossing is a form of inbreeding, and in species normally cross-fertilized it may result in a reduction of vigor. Sometimes it is advantageous to select several hybrids for backcrossing to various individuals of the parent type to explore combining ability and hidden genetic variations within the species. Repeated backcrossings of succeeding generations to the same parent tree will produce progeny that more and more resembles the parent type.

Exotic trees may not be suitable to new environments, making it necessary to cross endemic forms with them for greater adaptability and improvement of the local material. The backcross technique can achieve both of these objectives (Patel, 1938).

Inoculation of Hybrids. Hybrids require severe inoculation with the disease organism so that their resistance and susceptibility may be evaluated. The ideal setup, rarely attained in tree-breeding, is to have seedlings from both parent species on the same plot with the hybrid seedlings, all the same age and all to receive inoculation. The age at which the trees should be inoculated, the location on the trees which is to receive the inoculum, the technique of inoculation and the season of year should receive due consideration with respect to the pathogen and the way it naturally infects the host. The objective here is a severe inoculation, and it is advisable to inoculate the trees in different years to lessen the possibility of escape from infection. Many trees may be lost by these methods, but the breeder or pathologist cannot afford to proceed under a false assumption that his trees are resistant.

Results from inoculating F_1 hybrids derived from crossing a resistant tree with a susceptible one will indicate: (*a*) whether the hybrids are as susceptible to the pathogen as the susceptible parent; (*b*) whether they are less resistant than the resistant parent but more resistant than the susceptible parent; and (*c*) whether they will be as resistant as the resistant parent. Inoculation of hybrids derived from crossing resistant members of two races or species may yield a few individuals with resistance greater than either parent possessed. Such transgressive segregation of the character resistance sometimes occurs when inheritance of a character is controlled by many genes. The phenomenon may then also occur in a segregating generation such as the F_2. Inoculation of large numbers of F_2 trees will indicate the proportions which are resistant, intermediate in resistance and susceptible to disease.

When first-generation trees show complete susceptibility to a disease, the breeder has the choice of using selections of the resistant parental species as such, or of producing a second generation by intercrossing the F_1 trees. The inheritance of susceptibility as a dominant or incompletely dominant character means that only a small proportion of the second generation will prove resistant; the

number may be so small that mass production of resistant hybrids by this means is impracticable. In such a case the few resistant individuals may be increased by vegetative propagation. Intermediate resistance may incline in degree toward the resistant parent, and hybrids possessing this characteristic may be sufficiently resistant for distribution and planting if due consideration is given to soil and site factors so that both a maximum growth response and a minimum of damage from the disease are obtained.

Inbreeding and the Use of Inbred Lines. Inbreeding of some agricultural crops is necessary so that the plants, which are reproduced by seeding, will come true to type. Inbreeding selected hybrid types to obtain true reproduction would defeat an important objective of breeding trees for forestation, that of producing trees with a maximum rate of growth. Fixation of type requires several generations of inbreeding extending over many years and usually results in loss of vigor in normally cross-fertilized species, to which most of our major forest trees belong.

Some new tree hybrids no doubt would not reproduce efficiently by seeding, and in case others did, Righter (1946) suggested that a few vigorous seed trees be left in the planting for reproduction. Heterozygous generations would eventually take over, and in time the weak and disease-susceptible trees would pass out, leaving the area gradually to more vigorous and disease-resistant trees.

A more important purpose for inbreeding trees or tree hybrids is that of developing inbred lines. An inbred line is defined as a relatively homozygous line produced by inbreeding and selection (Hayes and Immer, 1942). Inbreeding trees that rarely set seed by self-fertilization is impracticable and may lead rapidly to deterioration of the progeny (Johnson, 1945). A slower approach to inbreeding is attained by crossing two selected trees and backcrossing a selection from the progeny to the selected parent tree. A selection of the later progeny is then backcrossed to the same parent tree. A number of inbred lines are established, and during each generation the lines are crossed with one another. The progeny is observed for exceptional rates of growth or what is commonly called " hybrid vigor ". Inbred lines are used in corn breeding for the production of " hybrid corn ". The possibilities of using inbred lines for the production of " super trees " should be explored in every tree-breeding project.

Sexual Propagation of Disease-Resistant Selections. The tree breeder must devise means to increase the numbers of his disease-resistant selections with the least effort and expense. An important advantage in sexually propagating a selection is that each individual is a distinct entity possessing minute genetic variations differing from those of its neighbors; thus each plant responds independently to the environment and to attacks of disease organisms.

Mass production of seed from a disease-resistant exotic species is simple; an orchard is established and maintained for the purpose. Mass production of hybrid seed from normally cross-pollinated trees is obtained in specially designed seed orchards. For production of seed of the first generation, grafts of the two parent trees are planted in orchard formation; for production of seed of the second generation, grafts of two selections from the first generation are used. Trees that normally set seed by self-pollination may not cross-pollinate readily in nature because of flower structure or lack of insects. Hybrids of such trees would be produced artificially and increased by vegetative propagation.

Vegetative Propagation and the Use of Clones. Of the two most practicable methods of vegetative propagation of trees, scion-grafting is more generally

successful and more costly, while propagation by cuttings is economically successful in comparatively few tree species. The tree breeder can afford to graft his selections only for small-scale operations, such as to induce early flowering and fruiting, and to establish disease gardens and seed orchards. Roberts (**1949**) reviewed the theoretical aspects of graftage. Considerable work has been done to develop practicable methods of propagating tree species by stem and root cuttings (Kains and McQuesten, **1942**; Mitchell and Rice, **1942**; Thimann and Behnke-Rogers, **1950**).

Vegetative propagation by cuttings is especially worthwhile for testing disease resistance and the comparative virulence of various races of a parasitic fungus. Schreiner (**1939***a*) set forth the possibilities in the use of clones in forestry, and Hartley (**1939**) and Stevens (**1948**) discussed the unfavorable implications of using clones. Differences between individual trees in the forest may be due to environment, but such differences can be eliminated, and true genotypic differences become obvious when rows of vegetatively propagated individuals are compared (Syrach-Larsen, **1947**). Clones also eliminate differences in genetic constitution and thus can be used as indicator trees in site evaluation and for comparison of environmental factors on disease resistance. However, the genetic uniformity of a clone planting favors the rapid progress of diseases to which it is susceptible and may also influence the building up of specialized races of parasites. For these reasons mixtures of different clones should be used in plantings.

Establishing New Disease-Resistant Trees

Choosing the Range and Type of Land. A knowledge of the ecological requirements of an exotic tree species is mandatory if failure of test and forest plantings is to be avoided. Use of bioclimatic principles for guidance in the distribution of exotic trees was mentioned previously. Knowledge of the latitudinal and altitudinal ranges of the exotic in its native land is important, since they reflect the nature of the soil, moisture and local climate preferred by the species. Choice of the type of land, whether for exotic or for hybrid trees, is equally important. Day (**1949**), discussing forestry in Great Britain, pointed to the danger of relegating land of low physical productivity to forestry and thereby increasing the liability for disease to occur in addition to the inadequate return resulting from poor growth rate. The availability of land space must not tempt the forest-tree breeder until he has conducted tests to prove its suitability. Old abandoned fields, subjected to depletion and erosion, reduced organic matter, decreased soil porosity and soil aeration must be avoided. On the other hand, tree planting is not justified on land that is level and fertile enough for profitable crop production, on land suitable for establishment of a successful permanent pasture for raising livestock, or on land that will reseed naturally and fully to desirable tree species in a reasonable time (Minckler, **1945**). However, some lands that are submarginal for agriculture may be excellent for tree growing (Burrage, **1941**).

Selecting the Habitat. The tree breeder, by selective breeding and hybridization, attempts to produce new forms embodying a maximum of desirable hereditary characteristics. When these objectives are attained, he or the ecologist with whom he cooperates must select the habitat which best expresses these characteristics (Schreiner, **1939***b*). The importance of habitat in relation to the genotype of the new tree may be realized from the following: (*a*) single Mendelian factors may vary widely in their expression because of differences

in environmental conditions; (*b*) distinct genetic types may be impossible to distinguish in one environment, and be quite different in appearance in another; (*c*) a suitable environment is necessary before any gene or combination of genes can have selective value; (*d*) the cumulative effect of modifying genes under a particular set of environmental conditions can be taken advantage of in improving the adaptability of selections having special appeal; (*e*) the value of any heritable character in a particular environment may bear no relation to its development or lack of development in another environment (Yarnell, **1942**). Factors of the environment responsible for these differences include moisture, temperature, light, nutrition and elevation or altitude, as affected by geographical and cultural conditions. Soil factors as related to the determination of site quality are comprehensively treated in two textbooks (Lutz and Chandler, Jr., **1946**; Wilde, **1946**), and more recently Gaines (**1949**) reviewed the principles of site evaluation from soil factors.

Planting and Management of Plantations. Planting and management of disease-resistant plantations should follow approved practices (Sand and Bryan, **1947**; Baxter, **1951**; Chapman, **1931**; Hawley, **1929**; Matthews, **1935**; Minckler and Chapman, **1948**); the extra effort and expense of importing an exotic or of producing hybrid seed and seedlings justify extra care. The importance of a favorable climatic region and proper sites for either exotic or hybrid trees is two fold: to obtain vigorous trees and to reduce damage from disease. The new disease-resistant trees should not be set out in pure stands unless the parental species naturally formed pure stands. If the trees are propagated as clones, there should be more than one clone to a stand.

The period of rotation will depend upon the principal use of the timber crop. If special value is attached to diameter quality, the rotation affording the greatest average net annual money yield will be longer than the rotation for maximum current growth. In the shorter rotation period, the stand is cut when it reaches a maximum increment of growth. The short rotation is consistent with our present economy, which is based on the ability to make many things from smaller sized trees at a profit both to the tree farmer and to the manufacturer (Gillett, **1950**). Short rotations also mean less liability of damage from disease, insect attack and wind damage (Div. of Forestry and Forest Products, F. A. O., **1950**). The short rotation is especially desirable when the stand consists of clones because of the greater risks of disease attacking the clones.

Reproduction from Hybrid Plantings. Of interest to the tree breeder and forester is whether reproduction by seeding from hybrid trees will be obtained and if so, whether such reproduction is desirable. Seedling reproduction of adapted native species is frequently uncertain, and plantations of hybrids, especially of hybrids carrying genes of an exotic species, may less frequently reproduce by seeding. If reproduction by seeding is obtained, it should be observed from time to time for growth and disease-resisting characteristics.

In the reproduction the proportion of seedlings resistant to disease will gradually increase as the original stand is selectively thinned; such artificial selection, aided by the effects of natural selection, will eliminate weak and disease-susceptible trees and leave the more vigorous and disease-resistant trees to interpollinate. However, any hybrid vigor that is characteristic of certain F_1 hybrids would probably characterize only a small percentage of succeeding generations. Natural reproduction by seeding results in new stands composed of mixed and uneven-aged trees, even though the parental stands consist of only a few

clones. The genetically heterogeneous seedlings in the reproduction would resist other parasitic diseases more effectually than the more genetically uniform parent trees of the original stand (Stevens, 1948). The silviculture of uneven-aged stands is more difficult, but it is the most flexible means of adapting forest production to special needs (Div. of Forestry and Forest Products, F.A.O., 1950).

Some types of hybrids from species of hardwoods may reproduce by stump sprouts, seedling sprouts or root suckers. Mature trees derived from stump sprouts are more subject to decay than trees originating from seedling sprouts or root suckers. Jemison and Hepting (1949) give instructions for handling sprout stands.

Segregating Generations in Reproduction from Hybrid Plantings. When the original stand consists of fertile hybrids, natural intercrossing will produce succeeding generations of hybrids. Natural and artificial selection will eliminate the weakest and most disease-susceptible trees, and, before the final harvest of the original hybrid crop, some later-generation trees will cross among themselves as well as with the parent trees. The continuing effects of natural and artificial selection will gradually increase the frequency of genes controlling disease resistance and adaptability in succeeding generations. In case a disease-resistant exotic is found not adaptable to the habitat except through hybridization with the native species, the segregating generations in the reproduction will include some individuals resembling the exotic parent. Natural selection will probably eliminate these, even though they are disease-resistant, because they are not adaptable. Other disease-resistant segregants with genotypes that are similar to those of the original hybrids and therefore more or less " hybridized to the habitat " will survive.

The speed with which artificial and natural selection affects the frequencies of genes conditioning disease resistance in hybrid seedling reproduction may depend on whether a few major genes or many minor genes (polygenes) are acting. Knight (1948) stated that major genes (genes exercising large effects) are more common in the control of disease resistance and of other economic characters than is generally realized. Mather, on the other hand (Anonymous, 1944), stated: " the great majority of characters involved in breeding programs show polygenic variation, depending on many genes having small, similar and supplementary effects ". The tree breeder can determine which type of genes control disease resistance and other traits in his hybrids from statistical studies of the inheritance of such traits. This knowledge may preclude errors that otherwise might be made during the progress of breeding and will provide a clearer idea of how resistance and other traits are inherited in hybrid reproduction.

Present-Day Breeding of Trees for Resistance to Disease

Breeding Chestnut for Resistance to the Blight. In this country chestnut was the first major species to be bred for resistance to a disease. Van Fleet (1914) began to breed chestnuts in 1894 to improve quality of the nuts. In 1909 he came to the Bureau of Plant Industry, U. S. Department of Agriculture, to breed chestnuts for resistance to the blight, caused by *Endothia parasitica*, which was spreading rapidly from New York City and killing stands and isolated trees of the native chestnut (*Castanea dentata*) and orchards of the European chestnut (*C. sativa*). Van Fleet (1920) used these species along with blight-resistant horticultural varieties of the Japanese chestnut (*C. crenata*) which had been introduced from Japan for some 40 years; the blight-resistant Chinese chest-

nut (*C. mollissima*), which was first introduced in 1906; and some species of native chinquapins, all of which were susceptible to the disease.

Van Fleet crossed the Japanese chestnut with the American and the Chinese, and the latter with the American chestnut. By 1937 all his hybrids that had American chestnut as one parent were blight-killed. Two trees, apparently crosses of the Japanese chestnut with the Chinese, survive today along with another hybrid derived from crossing Japanese chestnut with a chinquapin.

From 1925 to 1949 the writer took an active part in this breeding work. For the first 10 or 12 years most of the possible crosses between native species of *Castanea* and the blight-resistant Oriental species were attempted to determine crossability. A large majority of such crosses were successful. Many crosses were also made to improve quality of nuts, but the results were not especially promising. Other workers in the Bureau, studying the horticultural value of introduced selections of the Chinese chestnut, have recently released three new varieties to the trade (Reed, 1950; McKay, 1950).

In 1928 the American chestnut was crossed with the Chinese chestnut, and a few of the F_1 hybrids are still living; although of poor growth-form, they are highly tolerant of the blight. The native chestnut was also crossed with a horticultural variety of the Japanese chestnut in 1931, and with wild types of Japanese chestnut in 1932. For the most part, the F_1 hybrids are only moderately vigorous and not sufficiently blight-resistant although of good growth form.

In 1935 an American chestnut was crossed with each of two Chinese chestnut trees of the same race. The F_1 hybrids from one Chinese parent are the best from the viewpoint of growth rate, growth form and blight resistance thus far produced (Clapper, 1943; Ulm, 1948*a*). The hybrids from the other Chinese parent are decidedly inferior in that they have an abnormally high ratio of bark to wood, which resulted in drooping branches. Also, the bark of these hybrids cracked unusually early, at the age of three years, and this may have been responsible for their early blight infection and subsequent death. This experience demonstrated that important genetic variations, not discernible in similar trees, may occur within a race. Breeding experience has also shown that races of the Chinese chestnut when crossed with a single American chestnut yielded F_1 trees differing in growth form and blight resistance. From these experiences chestnut breeding now includes extension of hybridization to all available races of the Chinese chestnut as well as to a number of selections from each race. The American chestnut has nearly vanished, and there still appears to be little chance of finding a sprout or seedling with noticeable resistance to the blight.

The superior F_1 hybrids obtained in 1935 from crossing American with Chinese chestnut show an intermediate resistance to the blight that favors the resistant rather than the susceptible parent, and a growth rate and growth form similar to that of the native species. The trees were given a severe inoculation with the blight fungus in 1943 (Clapper, 1952); on most of the trees the cankers stopped growing at an early stage, and subsequently the wounds healed over. If it were possible to multiply these hybrids rapidly, they would be used extensively in trial plantations. The F_1 hybrids were backcrossed to the Chinese parent tree and to other Chinese chestnut types. Trees of the first backcross generation for the most part have the blight resistance of the Chinese parent, but unfortunately also similar growth rates and growth form.

In 1930 Graves (1931), then of the

Brooklyn Botanic Garden, began breeding chestnuts to develop a vigorous, highly blight-resistant timber tree, and this work is continuing. The U. S. Division of Forest Pathology cooperates in and helps support this project which has been sponsored since 1947 by the Connecticut Agricultural Experiment Station. Graves has made many types of crosses, and the significant feature of his work is incorporation of Japanese, American and Chinese chestnuts in his hybrids (Graves, 1949). For example, the Japanese is crossed with the American, and the hybrid is outcrossed to the Chinese. This type of outcross may be considered as a wide form of backcross if the genes controlling characteristics of growth and blight resistance act similarly in the Japanese and Chinese chestnuts. Graves' latest development is crossing these Japanese-American-Chinese hybrids with the American chestnut to increase their stature. If the new hybrids are too susceptible to the blight, selected trees will be crossed with the resistant parent species (Graves, 1950). Since 1947 some of the best selections and hybrids of Graves' and Clapper's are going into the same forest test plantings (Clapper, 1950; Graves, 1949).

In the period 1927–36 large quantities of seed of the Chinese and wild forms of the Japanese chestnut were imported from China and Japan. Numerous forest test plantings were made from the New England States west to Iowa and south to the Gulf States. Diller (1940, 1950) reported that for best results Oriental chestnuts and hybrids should be planted on soils of average or better than average quality, and that the Chinese chestnut is adaptable to a greater area of the eastern United States than is the Japanese. Diller (1946) also developed a method of establishing the new chestnuts as forest plantings, by underplanting a fully stocked stand of hardwoods, preferably of pole size, and girdling all overstory growth five feet or more in height. The method is somewhat similar to that which Bull (1939) used to obtain increased growth of loblolly pine. Sites preferred by the new chestnuts are those on which the predominant species are yellow-poplar, northern red oak, white ash and sugar maples. Other methods of establishing chestnuts are to plant under openings in the forest canopy and around cut stumps after thinning or partial cuttings. Diller recommended that forest plantings of chestnut be held to small areas, in each of which a single variety or race is planted, so that sources of pure seed would be available. The same recommendation can be made for plantings containing a single type of hybrid, so that the succeeding generation obtained by natural seeding can be studied.

Some methods of establishing blight-resistant chestnuts and hybrids have been successful, but the problem of rapid increase of selected hybrids is still unsolved because a practicable method of vegetative propagation has not yet been developed. The leaf bud method of propagation has given some success in preliminary tests (Bretz, 1950), but further details of procedure are needed. The extreme susceptibility of the American chestnut to the blight requires that natural crossing plots using this species be established outside the range of the blight fungus.

In 1938 chestnut blight was discovered on European chestnuts in Italy, and it threatens the extinction of that species (Pavari, 1949). Italian tree breeders and pathologists have initiated the standard program of (*a*) preventive and curative experiments, (*b*) search for resistant trees of the European chestnut, (*c*) introduction of Oriental species of *Castanea*, and (*d*) hybridization (Pavari, 1949). The end-product that the Italians are striving for, however, is a tree which produces tasty nuts and which

is resistant to both the blight and the deadly rootrot fungus (*Phytophthora cinnamomi*). Chestnut breeders in this country are cooperating with the Italians by shipping them pollen, seed, seedlings and scions from selections of the Chinese chestnut and its hybrids (Gravatt, 1949; Graves, 1947; Pavari, 1949).

Breeding White Pines Resistant to Blister Rust. White pine blister-rust (*Cronartium ribicola*) is an introduced fungus disease that attacks eastern white pine (*Pinus strobus*) and other white pines native to the United States. The fungus spreads to pines from the alternate host plants—cultivated and wild currants and gooseberries, commonly called ribes—and from the pines the fungus spreads back to the alternate hosts. The disease is controlled by eradicating these alternate host plants. Control methods by eradication of the alternate hosts were developed some years after blister rust was discovered in 1906. Nearly 14½ million acres of the total 26 million acres of blister rust control area were under control at the beginning of 1951. Initial phases of control have been applied to an additional ten million acres. Acreage which has been brought under control requires only a low-cost maintenance program to keep it safe for white pine. Of eight native species of white pine, three are leading timber species. The white pines are adaptable to a wide range of site conditions, they make rapid growth and they lend themselves to forest management (Martin and Spaulding, 1949).

Childs and Bedwell (1948) investigated the susceptibility of white pines to blister rust, and classified their resistance and susceptibility as follows: Resistant—*Pinus armandi, P. griffithii, P. koraiensis;* moderately susceptible—*P. aristata, P. peuce;* susceptible—*P. flexilis* var. *reflexa* (formerly *P. strobiformis*), *P. strobus, P. flexilis;* very susceptible—*P. monticola;* exceedingly susceptible—*P. lambertiana, P. albicaulis.* Six of these pine species were investigated earlier by Hirt (1940) whose results are similar. He also determined that *P. cembra* var. *helvetica* is resistant to blister rust. All four species found resistant to blister rust are native to foreign countries.

Snell (1931) and Riker and Kouba (1940) reported rust-resistant trees of eastern white pine. Mielke (1943) located a resistant tree of western white pine. Since 1927 Hirt (1948) has investigated, with promising results, eastern white pines resistant to blister rust. His investigations are to continue in the hope of developing a highly resistant " line " of eastern white pine. Success in locating and breeding rust-resistant native white pines may lessen the need of establishing foreign species of white pines.

Riker et al. (1943) began in 1938 to select and test eastern white pines for resistance to blister rust. Selections of apparently resistant trees were made in areas of oldest infections in Wisconsin. These selections were propagated by seed and by grafting—the former method to determine whether resistant individuals appeared in the progeny of the mother trees, and the latter to determine, from inoculation of the grafts, whether the mother trees were truly resistant to rust. The results showed: (*a*) that artificial inoculations were much more severe than either natural inoculations in the disease garden or any natural rust epidemic in Wisconsin; (*b*) that natually inoculated pine grafts did not develop rust, while those grafts that were artificially inoculated did, although not to the same degree as the inoculated seedlings; and (*c*) that seedlings from selected mother trees rusted severely after artificial inoculation. Thus, by using severe artificial inoculations, the investigators were not misled in assuming that the naturally inoculated grafts were immune. They deduced that if

seedlings of selected mother trees did inherit rust resistance, it was not evident; that possibly a low degree of resistance might have been obscured by the severity of combined natural and artificial inoculations, or, rust resistance in the seedlings might not have been inherited as a dominant character. It is unfortunate that none of the apparently rust-resistant mother trees in this well designed experiment possessed a sufficient degree of resistance to be of significance in the seedling progeny.

Hybridizing white pines began in this country only in recent years. Workers at the Arnold Arboretum of Harvard University and at the Institute of Forest Genetics have observed hybrid vigor in hybrids between *Pinus strobus* and *P. monticola*, *P. monticola* and *P. griffithii*, and *P. griffithii* and *P. strobus*. The resistance of these hybrids to blister rust is under investigation (Stockwell and Righter, 1947). Stone and Duffield (1950) obtained seed from the rust-susceptible *lambertiana*, using pollen of *armandi* and *koraiensis*—two Oriental rust-resistant species. Germination of the seed soon after harvest was facilitated by a modified embryo culture technique. They suggest the possibility that a chilling treatment given to the greenhouse-grown seedlings when they enter the dormant period may produce plants the size of two-year-olds within a year. Other interspecific hybrids, even with no more vigor than the parent trees, should be of economic value if they are highly rust-resistant.

Johnson (1945) investigated the effects of self-fertilization in white and other species of pine. He found that self-fertilized white pine set seed as efficiently as open-pollinated trees, but the first-generation seedlings showed markedly reduced vigor, and about 20 percent of these showed pronounced chlorophyll deficiency. Apparently only one generation of self-fertilization in white pine, which is normally cross-fertilized, results in too close inbreeding. A more gradual form of inbreeding of possible use to pine breeders is that of parent-offspring matings.

Vegetative propagation by cuttings of white pines has been explored within the past 12 years with promising results (Deuber, 1942; Doran, 1946; Farrar and Grace, 1942; Mirov, 1938, 1944; Snow, 1940; Thomas and Riker, 1950). Grafting pines is generally less difficult than rooting them from cuttings (Mirov, 1940).

Boyce (1948), discussing rusts of conifers, considers the use of exotic white pines to replace native pines as not encouraging, and believes that long-time tests of exotics should be made before they are grown extensively. Even the use of resistant races of pines would have limitations because progeny of resistant trees will cross with susceptible trees. And although resistant trees were continually being planted, it would take generations for the rust fungus to eliminate susceptible trees until only resistant ones remained. Some pine breeders and pathologists, on the other hand, view the possibilities of using new rust-resistant forms as promising (Duffield and Stockwell, 1949; Martin and Spaulding, 1949; Stockwell and Righter, 1947). It should be possible to grow new forms of rust-resistant pines in isolated plantations and on areas that have been cut clear of rust-susceptible pines to prevent the two types from crossing. If exotic species of pines do not adapt well, hybridizing them with native species will increase the adaptability of the new rust-resistant forms (Patel, 1938).

The rust fungi that attack cereals frequently develop physiological races, and grain breeders must continually breed for resistance to new races. No evidence has yet been presented that physiological races exist in *Cronartium ribicola*, the fungus causing white pine blister-

rust (Boyce, 1948; Hahn, 1949*a*, 1949*b*; Mielke, 1943; Riker et al., 1943). Hahn's observations were based on the rust-free condition of immune clones of currants exposed for several years to rust-susceptible white pines in various geographical regions. An alternate test, wherein rust-immune or highly resistant clones of white pine are exposed to rust-susceptible ribes, should be made, not only for an additional check on the nonexistence of physiological races but also because of the greater importance of this subject to white pine than to ribes.

Breeding Elms Resistant to Dutch Elm Disease and Phloem Necrosis. The Dutch elm disease, caused by the fungus *Ceratostomella ulmi,* was first discovered in Holland in 1919. About seven years later the disease had infected American elm shade trees in Cleveland, as determined by examinations in 1930 of the infected wood (May, 1930). The disease is now established in 19 States and the District of Columbia in the eastern United States and in Colorado. It is spread by two species of bark beetle which carry the fungus from previously infected elms and from infected dead or recently cut elm wood. Both the beetle carriers and the fungus were discovered in 1933 on elm burl logs that had been shipped from Europe to our eastern seaboard (Beattie, 1933), thus demonstrating the method of entry to this country. The beetles can be controlled by spraying ornamental, park and street elms and such breeding material as recently cut, dead or dying elms (Swingle and Whitten, 1950; Swingle et al., 1949). There are no practicable methods of controlling the disease or the beetles on forest elms (Swingle et al., 1949; Walter et al., 1943).

The American elm (*Ulmus americana*) is one of our most important shade and ornamental tree species, and is extensively planted as such from coast to coast. As a forest tree it is an important component of mixed hardwood stands from the Great Plains area to the Atlantic Coast. Within this area are five other native elms—slippery elm (*U. fulva*), rock elm (*U. thomasii*), wing elm (*U. alata*), red elm (*U. serotina*) and cedar elm (*U. crassifolia*), all of which are susceptible to the Dutch elm disease (May, 1934). Among the Asiatic species of elm, *U. pumila, U. pumila* var. *arborea* and *U. parvifolia* are resistant to the disease (May, 1934). The English elm (*U. campestris*) and the Scots elm (*U. glabra*) are also susceptible; however, the disease on the former is less severe than on American elm (Beattie, 1937). The most promising disease-resistant selection, named "Christine Buisman" in honor of the Dutch scientist who discovered it, is reported as belonging to *U. carpinifolia* and has proved highly resistant in both Europe and America (Smucker, 1944; Swingle et al., 1949). According to more recent information (Swingle, 1950), however, the Buisman elm, which has been highly resistant to both Dutch elm disease and phloem necrosis, was found to be susceptible to one virulent strain of the Dutch elm disease fungus.

Investigation of American elms for resistance to the Dutch elm disease has received attention in the U. S. Department of Agriculture since the discovery of the disease in Ohio in 1930 and has been a major project since 1937 (Smucker, 1944). Thirty-five thousand elm seedlings collected throughout the natural range of the species were grown in test nurseries. The seedlings were inoculated with the causal fungus, with the result that only two withstood inoculations in three consecutive seasons, and these have since proved susceptible to new strains of the fungus. From about 20,000 controlled crosses between American and Siberian elm, less than 100 seeds were obtained, and only a small number of these germinated. Of the hybrids obtained, one resisted repeated inoculations

with the fungus but has recently been lost to the disease. The small number of seeds obtained from controlled crossings may be due in part to the difference in chromosome numbers—American elm having the diploid number of 56 and Siberian elm having 28 (Smucker, 1944)—and in part to variations in the technique of pollination and in the weather at the time of pollination. Nine seedlings resulted from nearly 500 crosses between rock elm and Siberian elm.

Elm flowers average one-eighth of an inch in diameter, and both male and female parts are borne in the same flower. In the first breeding attempts, workers carefully emasculated each flower when preparing it for controlled pollination. A breeder could prepare about 40 flowers per hour. Studies (Smith and Nichols, 1941) of the sequence of development of the reproductive organs indicated that the female part or stigma is receptive before the anthers shed pollen. This sequence permits crosses to be made without tedious manipulation if pollen from the selected tree is applied to the stigmas of the mother tree at the proper time. The technique has been used extensively with good results (Smucker, 1944).

Wright (1949) obtained production of seeds on cut branches of elm brought indoors. The flowers were pollinated by shaking a flowering branch from a different tree of the same species over them. Such indoor pollinations can extend the breeding season by two to eight weeks; the breeder can pollinate early-blooming trees by late-blooming ones; he can work trees from several localities at the same time, and he can guard against loss of flowers by unfavorable weather.

Elms may hybridize naturally where two or more species grow within pollinating distance; therefore, several thousand seedlings were collected by elm breeders in the Department of Agriculture from mixed plantings of American elm, slippery elm and Siberian elm in the Great Plains region. The Siberian elm is resistant to the Dutch elm disease, and some of these seedlings may prove to be resistant to the disease (Smucker, 1944).

The possibility of breeding disease-resistant elms of stature and form equal to the American elm may be realized in the future. At present only the Buisman elm has been distributed to nurserymen (Anonymous, 1949; Swingle and Whitten, 1950). This selection does not make the large graceful tree characteristic of American elm. Use of new techniques of pollination for crossing the Buisman and American elms may produce large numbers of hybrid seedlings from which to select resistant trees with more desirable characteristics.

Phloem necrosis, a virulent systemic virus disease of the American elm and the winged elm, was first reported in Ohio in 1918. In 1937 and 1938 pathologists in the U. S. Department of Agriculture made thousands of plate cultures to determine the causal organism, but without success. Attempts were then made to transmit the disease through graft unions, and this was successful, thus demonstrating a virus as the cause of phloem necrosis (Swingle, 1938, 1942). Later, entomologists and pathologists discovered that the virus is transmitted from tree to tree by a species of leafhopper (Swingle and Whitten, 1949). Phloem necrosis is present in 15 States and has killed thousands of American elms. Arborists have estimated the cost of removing trees killed by the disease in cities in 1944 alone at a half to three-quarters of a million dollars. Since both the virus causing phloem necrosis and the fungus causing Dutch elm disease are transmitted by insects, some control of these diseases is obtained by use of sprays, and a spray schedule has been proposed for the control of these insect carriers (Liming et al., 1949; Swingle, et al., 1949).

A few shade-tree type American elms have survived in some areas where phloem necrosis has been present for many years. Resistance tests on seedlings and clones of these survivors were encouraging (Swingle, 1945). The U. S. Department of Agriculture now has nearly 2000 American elms selected for their resistance to phloem necrosis. These should offer great possibilities, both by intense selection and by hybridization, in obtaining pure American elms carrying a high degree of resistance to the disease. Unfortunately no American elms have been found that are resistant to both Dutch elm disease and the phloem necrosis (Baker and May, 1951). Asiatic elms and European elms, including the Christine Buisman, are not affected by phloem necrosis.

Establishment of new elms resistant to the Dutch elm disease and to phloem necrosis depends in part upon successful methods of vegetative propagation. Recent investigations (Doran and McKenzie, 1949) showed that softwood leafy stem cuttings of *Ulmus americana*, *U. pumila*, *U. parvifolia* and *U. japonica*, when treated with growth-promoting substances, rooted well in sand. The Buisman elm with similar treatment did not root. Bretz and Swingle (1950) used leaf-bud cuttings and obtained efficient rooting with use of growth-promoting substances and a fine mist spray to maintain high humidity. These methods were successful with *U. americana*, *U. pumila*, *U. thomasii* and *U. fulva*, but were not successful with the Buisman elm. Root cuttings, planted in March, with the proximal ends exposed, have proved to be the most satisfactory means of propagating the phloem necrosis-resistant and Dutch elm disease-resistant Christine Buisman selection of *U. carpinifolia*.

Selection of Mimosas Resistant to Mimosa Wilt. The mimosa or silk tree (*Albizzia julibrissin*) is a native of eastern Asia and is grown widely as an ornamental and shade tree in the southern States. Its popularity is due both to its beauty and to its capacity to thrive on many types of soil. Mimosa wilt first attracted attention of pathologists in North Carolina in 1935 (Hepting, 1936, 1939; Toole, 1941). By 1947 the disease was found in 82 counties in six States from Maryland to Alabama (Toole, 1948*a*). The causal fungus was isolated from infected mimosas and named *Fusarium oxysporum* f. *perniciosum* (Toole, 1941). The fungus is present in the soil and is disseminated by transportation of infested soil and by transplanting infected host plants. There is no practicable method of controlling the disease, although preliminary results suggest that application of fungicides to the soil may be useful for the protection of valuable trees (Toole, 1950). Inoculation tests of various species of *Albizzia* showed *A. lebbek*, *A. lophantha* and *A. kalkora* to be susceptible, and *A. thorelii* to be resistant to the wilt (Toole, 1941).

The search for wilt-resistant mimosas was begun in 1939 by pathologists in the U. S. Department of Agriculture. Seed was collected from trees ranging from Maryland to southern Louisiana. More than 500 seedlings were grown, and repeated inoculations reduced this number to 31 trees, which were planted in wilt-infested soil for further observation (Hepting and Toole, 1942). Twenty of these trees, representing four different parent trees of *A. julibrissin* and one each of *A. julibrissin* var. *rosea* and *A. kalkora*, remained wilt-free for eight years. In the meantime some of these selections produced seed, and after the seedlings were inoculated, 56 percent survived (Toole, 1949; Toole and Hepting, 1949).

Extensive experiments on the vegetative propagation of mimosa, with material from various parts of the tree, demonstrated the rooting superiority of

root cuttings over stem cuttings, and hardwood over greenwood cuttings. The propagation box gave better results than the greenhouse bench, and no storage was preferable to pre-storage of cuttings (Toole, 1948*b*, 1949; Toole and Hepting, 1949).

At the present time the wilt-resistant mimosa selections are being tested further in small plantings in various localities throughout the Southeast. The stock is being increased by vegetative propagation, and within a few years wilt-resistant trees should be available through commercial channels (Toole, 1949). Hybridization of the several species of *Albizzia* has not been attempted in view of the practical success with vegetative propagation of resistant selections.

Breeding Poplars Resistant to Leaf and Stem Diseases. Pauley (1949) reviewed the research on *Populus* and listed an extensive bibliography. This review deals chiefly with diseases affecting poplar and some of the results obtained from test plantings of hybrid poplar selections.

The poplar breeding project was an early large-scale production effort in breeding a forest-tree species. Thirteen thousand hybrid seedlings were produced from nearly 100 different cross-combinations between various types of poplars, including species, varieties and hybrids propagated as clones. Selections from the young hybrids made on the basis of vigor, ability of stem cuttings to root, hardiness and resistance to disease yielded 69 plants in 1932. These plants as clones were widely distributed for testing under various soil and climatic conditions (Stout and Schreiner, 1933).

In this country a number of serious diseases attack poplars and poplar hybrids. Among these are cankers caused by *Cytospora, Dothichiza, Hypoxylon, Nectria* and *Septoria;* dieback caused by *Cytospora* and *Napicladium;* leaf rust caused by *Melampsora;* also leaf spots and twig diseases (Pauley, 1949). Some hybrids have shown practical immunity to Melampsora rust and Fusicladium twig disease (Schreiner, 1937; Nagel, 1949). Bier (1939) stated that *Septoria musiva* is an example of a native fungus of minor importance causing a leaf spot on native poplars, which may act as a virulent canker-producing parasite on new hybrids and exotic poplars.

Waterman (1946) reported Septoria cankers on hybrid poplar clones in two plantings in New York State and in one at Norris, Tennessee, and stated that on less susceptible trees, Septoria cankers may become infected by secondary fungi, such as *Cytospora,* which grow more rapidly than *Septoria* and tend to mask its presence. Her inoculations of ten clones of poplar hybrids that have proved particularly adaptable for forestation indicated that four clones were highly susceptible. Schreiner instigated studies of an unknown fungus causing a leaf blotch of poplars and hybrids, and later Waterman and Cash (1950) reported on the cultural and pathological phases and the identity of the causal organism (*Septotinia populiperda*). The conditions favoring spread of the disease in plantings of hybrid poplar clones and the relative susceptibility or resistance of native and introduced poplar species are being studied.

A number of reports on poplar hybrid performance in test plantings have been published. To mention a few—Blow (1948) reported on plantings of ten clones in the Tennessee Valley. Susceptibility to cankering appeared important on all clones except one. The growth and yield of these hybrids was not outstanding, and establishment of hybrid poplars in the Valley for production of pulpwood was not recommended. Rudolf (1948) presented a comprehensive report on poplar hybrid plantings in the Lake States. His evaluation of the re-

sults showed that these plantings were disappointing and that the hybrids so far tested cannot replace any of the species commonly used under ordinary planting conditions. He recommended continued search for native poplar selections for growth or wood quality for use in crosses.

According to Schreiner (1949), poplars for reforestation in this country suffer because of two handicaps: they are susceptible to diseases that under certain conditions can wipe out an entire plantation, and they require considerable care in planting and are highly intolerant of both top and root competition. He believes that carefully selected hybrids will largely eliminate the disease hazards.

In 1947 the Northeast Forest Experiment Station began once more to build up its growing stock of 200 selected poplar hybrids for comprehensive tests in forestation throughout the northeastern States. The hybrids were selected for resistance to diseases after being subjected to 20 years of natural selection in western Maine. This period is longer than that required by one rotation of poplar for pulpwood. The trees are being further subjected to direct inoculation tests (Schreiner, 1949). New plantings are being and will be made under more ideal conditions than formerly to adequately test the new hybrids.

Summary

Success in the breeding of trees resistant to disease depends upon (*a*) availability of disease-resistant individuals within the affected species or in related species; (*b*) compatibility of the genetic constitution of the selections necessary to the development of new resistant types and to the production of hybrid seed stocks; (*c*) the method of inheritance of factors controlling disease resistance and other essential characteristics such as growth rate and form; and (*d*) efficient and economical methods of vegetative multiplication of the selections. After new disease-resistant selections are obtained, their successful establishment depends upon proper selection of climatic regions, adaptability to sites, planting technique and care of the plantings.

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Plant Disease Control with Antibiotics

The great importance of antibiotics in combating diseases of man has, along with economic factors, deterred investigators from exploring the possibility of using those agents against plant diseases, but some purely experimental evidence in that direction has been accumulated.

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This review will be limited to publications dealing with antibiotic substances, adequately defined chemically or biologically, which have been used for attempted control of diseases incited by plant pathogenic organisms. It excludes, for example, many reports on antagonism between soil microorganisms where apparently some antagonist, through production of an antibiotic substance, was responsible for reduction in the severity of a given disease or reduction of the parasitic organism in the soil. There are a number of available reviews dealing with antagonism in general (Waksman and Foster, 1937; Porter and Carter, 1938; Waksman, 1940, 1941). Garrard and Lochhead (1938) presented a review on the relation between soil microorganisms and soil-borne plant pathogens, and in the same year Weindling (1938) reviewed the literature on association effects of fungi, in which he summarized a number of articles dealing with antagonistic effects and the conditions under which the antagonistic substances were produced. In 1945 Waksman devoted a chapter of his book on microbial antagonisms to microbiological control of soil-borne organisms, in which he reviewed most of the publications between 1938 and 1945 as well as those previously treated in the above mentioned publications.

Gliotoxin

Gliotoxin has the distinction of having been the first antibiotic to be crystallized. In 1932 Weindling observed the marked antagonism, to a wide variety of fungi, of an organism thought to be *Trichoderma lignorum* but later identified as *Gliocladium fimbriatum* (Weindling, 1937). Generally the aerial hyphae of *Gliocladium* attacked the aerial parts of plant pathogenic fungi by winding around them; on the other hand, the submerged hyphae of a susceptible fungus were more often attacked at a distance from the parasite (Weindling, 1932). This antibiotic inhibited a wide range of both fungi and bacteria. It was produced in a simple liquid medium during the growth of *Gliocladium fimbriatum, T. viride* and *Aspergillus fumigatus* (Weindling, 1934, 1941; Brian, 1944, 1946; Brian and Hemming, 1945; Menzel et al., 1944; Glister and Williams, 1944).

Pure crystalline gliotoxin is readily obtained by simple extraction with chloroform and subsequent recrystallizations. It is an acidic material with the empirical formula $C_{13}H_{14}N_2O_4S_2$ (Weindling and Emerson, 1936; Johnson et al., 1943). The structural configuration of this compound was described by Dutcher et al. in 1945, and its antibiotic activity was associated with an unusual type of

sulfur linkage. Other studies have been reported by Dutcher et al. (1944) and by Bruce et al. (1944). The compound is unstable in basic solutions but very stable in highly acidic environments; light is also deleterious to this material (Weindling, 1937, 1941; Johnson et al., 1943).

The activity of gliotoxin against fungi and bacteria has been expressed in various ways, depending on the investigator. According to Weindling (1941), the L.D. 50 for germination of *Rhizoctonia solani* is 1 : 300,000 and for *Sclerotinia americana* 1 : 450,000. Reilly, Schatz and Waksman (1945) reported inhibition of some common mycelial fungi in concentrations from 1 : 200,000 to 1 : 600,000, while some of the animal pathogens were affected between 1 : 2,000,000 and 1 : 20,000,000. *Ceratostomella ulmi* was inhibited at 83 μg. per ml. (Waksman and Bugie, 1943), and Brian (1944), has reported inhibitory concentrations for a few fungi between five and 40 μg. per ml. Many bacteria are inhibited between 0.2 and 13 μg. per ml. (Johnson et al., 1943; Rake et al., 1943; Schatz and Waksman, 1944; Brian, 1944).

The role of gliotoxin in controlling disease or influencing the microflora of the soil has received much attention. In his first paper, Weindling (1932) suggested the incorporation of *Trichoderma lignorum* into soil for the control of plant pathogens. By this procedure Weindling and Fawcett (1936) reduced the "damping-off" of citrus seedlings. Similar results were obtained by Christensen (1936) with sterile soil; the stand of barley seedlings was greatly increased when the plants were grown from seed inoculated with *Helminthosporium sativum*, but this method failed when naturally infected seed or non-sterile soil was used. The protective action of *T. lignorum* against soil-borne plant pathogens was also demonstrated by Bisby et al. (1933) with *H. sativum* and *Fusarium culmorum*, and Anwar (1949) noticed a similar reduction of disease due to *H. sativum* in the presence of *T. lignorum*. Under like conditions, no control of flax wilt caused by *Fusarium lini* was observed. Not only can the invasion of underground plant parts be minimized by this antagonist, but the organism can even protect above ground parts of the host plant. Matsumoto (1939) introduced *Trichoderma* simultaneously with *Corticum sasakii* into leaves of *Eichhornia crassipes;* the presence of the former organism reduced the amount of invasion by the pathogen. *Trichoderma* is also effective in protecting cucumbers and peas from *Pythium* and *Rhizoctonia* (Allen and Haensler, 1935). The studies of Weindling and Fawcett (1936) indicate that the lability of gliotoxin to alkali is reflected in the different activities of the antagonist at various levels of hydrogen ion concentration of soil; at pH 7.0 no control of damping-off occurred, whereas in more acid soils the number of plants surviving attack increased. When used as a seed protectant, gliotoxin reduced the covered smut of barley, bunt of wheat and *Helminthosporium* leaf spot of oats, but it was inferior to the organic mercurials (Brian and Hemming, 1945). Van Der Laan (1947) showed that this antibiotic had considerable protective action against *Cercospora nicotianae* when applied to tobacco leaves, without any apparent toxicity.

To the gliotoxin-producing organisms has been attributed an important role in determining the balance of the microflora in the soil (Brian, 1944). The failure of conifers on the Wareham heath soils in England has also been ascribed, in part, to deleterious effect of this antibiotic on the mycorrhizal fungi which are normally associated with such trees (Brian et al., 1935). Nevertheless, no gliotoxin has ever been isolated from soil.

Penicillin and Streptomycin

One of the earliest reports of the control of a plant disease by the use of a known antibiotic was that of Brown and Boyle in 1944. While penicillin was not used in a purified state, the fact that a known penicillin-producing culture of *Penicillium notatum* was employed to produce the " crude penicillin " was good evidence of the nature of the antibiotic. The injection into galls, produced by inoculating plants of *Bryophyllum* with *Agrobacterium tumefaciens*, of a culture solution containing six Oxford units per ml. resulted in checking the growth of these tumors. When cotton wool, soaked in this crude penicillin solution, was applied to the surface of the gall, its tissue gradually became necrotic, whereas the healthy tissue beneath was only slightly injured. No evidence for the antibiotic effect of penicillin on the pathogen in vivo was reported, and later studies indicated that the effect was largely on the gall host tissue (Brown, 1944*a*, 1944*b*, 1945). *Agrobacterium tumefaciens* was known to be fairly resistant to penicillin, as indicated by Waksman, Bugie and Reilly in 1944.

In 1948 Brown reported further on the cytological effect of streptomycin on crown gall; he stated that living gall cells as well as the bacterial inciter, *Agrobacterium tumefaciens*, were killed by application of penicillin and streptomycin. Healthy host tissue in the neighborhood of the treated galls was not affected. In this year Hampton reported on the use of streptomycin- and penicillin-saturated pads for " curing " crown gall on numerous plants. In 1949 de Ropp presented detailed study of the action of antibacterial substances on the growth of *Agrobacterium tumefaciens* and of crown gall tumor tissue. He found that penicillin was much less effective than aureomycin, chloromycetin, streptomycin and streptothricin against the organism. If antibiotics were added to carrot slices one day after they were inoculated with the pathogen, tumor formation was inhibited. Penicillin G was effective only at high concentration, but streptomycin prevented the galls at much lower concentrations. Once the tumors were formed, they were not caused to regress by either penicillin or streptomycin. Favorable results in disease control were also reported by Boyle (1949); the necrotic lesions of giant cactus caused by *Erwinia cornegiana* were eliminated after penicillin injections.

Valeria Van Schaack in 1948 gave a brief report on the control of potato ring rot (*Corynebacterium sepidonicum*) by penicillin and streptomycin. These antibiotics were applied to inoculated cut seed pieces which were then planted. Inoculated but not treated seed pieces did not grow but rotted in the soil. The inoculated penicillin-treated pieces also failed to grow. Inoculated and streptomycin-treated seed gave a high percent of healthy plants as did the uninoculated untreated controls.

Elimination of *Xanthomonas pruni* from cankers on plum twigs was reported in 1946 by Brown and Heep. In these experiments they used sections of twigs five to six inches long, such as are used for budwood in propagating plums in the nursery. The cankers were typical of the bacterial spot on plum. Streptomycin culture solutions of six to eight Oxford units and " strong concentrations of the crystalline drug in sterile distilled water " were used. The bud sticks were placed in a chamber with their bases immersed in the solution and submitted to negative pressure. At the end of 24 hours treatment, no bacteria could be recovered from the cankers, while the organism was cultured from control twigs subjected to the same treatment but using distilled sterile water in place of the streptomycin. The organism was also recovered from the twigs before they were treated. There was no injury to

the dormant buds, for they developed normally, even after the treatment. Injections of penicillin solutions into trees to control pear blight, caused by *Erwinia amylovora*, and walnut blight, caused by *Xanthomonas juglandis*, were unsuccessful, despite the fact that concentrations much higher than the strength necessary to inhibit the bacteria in vitro were used (Rudolph, 1946).

Streptomycin has also been tried as a protective spray by Ark. Under greenhouse conditions, tomato plants sprayed with streptomycin (concentration not given) one to 24 hours before inoculation with *Pseudomonas punctulans* did not develop the leaf spot in 30 days, while the checks showed symptoms in four days. He states, however, that under field conditions, sprays of streptomycin at concentrations of one p.p.m. completely failed to control walnut blight caused by *Xanthomonas juglandis* (Waksman, 1949).

Absorption and translocation of streptomycin were reported in 1947 by Anderson and Nienow. They grew soybean plants in Shives solution, to which a relatively non-toxic concentration of streptomycin sulfate was added. The expressed sap yielded four to five μg./ml. of the antibiotic. When these plants were inoculated with *Xanthomonas phaseoli* var. *sojense*, typical lesions developed, from which the organism could be isolated.

Early in the investigation of antibiotics for control of plant pathogenic microorganisms, it was postulated that these materials might prove useful in freeing seed of pathogenic bacteria. Most of the antibiotics available at that time were not effective against the fungi which cause damping off and root rot. Early unpublished results with clavacin and crude streptomycin indicated that these materials when used at relatively low concentrations inhibited the germination of most seeds.

In 1946 Ribeiro reported the results of experiments in which he tested the effect of penicillin on seed germination. He did not state the source of the penicillin used or its purity. The seeds used were of French lettuce (*Lactuca sativa* var. *capitata*). They were floated on solutions of the antibiotics, and germination was observed at 24 and 48 hours. The dilutions were from 0.1 to 1,000 Oxford units per cc. The seeds failed to germinate at concentrations above ten units and were decidedly retarded at concentrations as low as 0.5 unit. If after 48 hours in the solution the seeds were removed to pure water, they started to germinate. He reported that an attempt was made to use this germination test as an assay method but that on subsequent trials it was found unsatisfactory, since his results were too erratic. Smith in 1946 called attention to the fact that Ribeiro's results may have been due to the presence of impurities in the penicillin used. He found in all lots of therapeutic preparations tested that the presence of phenylacetic acid, indoleacetic acid and formic acid could be detected. Each of these substances when tested separately was active in inhibiting seed germination. Indole-3-acetic acid was regarded as the probable inhibitor in therapeutic penicillin. Pure dihydro F and G had no inhibitory effect. In a comparison of pure and crude penicillin and of streptomycin sulfate he found that at 0.5 mg./ml. the crude materials were much more toxic than the pure. He concludes that both penicillin and streptomycin when freed of indoleacetic acid are relatively non-toxic to seed germination and growth.

In 1949 McKeen, in a study of sugar beet root rot in southern Ontario, caused mainly by *Aphanomyces cochlioides*, *Pythium aphanidermatum*, *P. ultimum* or *Rhizoctonia solani*, tested the effect of penicillin and streptomycin as a seed treatment for protection against the root

rot organisms when seeds were planted in a naturally infested soil. Penicillin was ineffective, but streptomycin showed good protection against the rots. The beet seeds were soaked for 48 hours at 5° C. previous to planting. A ten percent solution of streptomycin caused injury, but at five percent no phytotoxic effect was noted, and root rot was completely controlled. However, at 0.2 percent strength some root rot developed (22.2% against 74% in control).

Ark (Waksman, 1949) presented results on the control of certain bacterial diseases of plants by the use of streptomycin. In his own experiments cucumber seeds were soaked in streptomycin soljutions varying in concentration from 1–10,000 to 1–1,000,000, then dried and placed on plates seeded with the angular leaf spot organism, *Pseudomonas lacrymans*. Clear zones varying in diameter similar to those obtained with paper discs resulted. He demonstrated that cucmber seeds soaked for 24 hours germinated as well as non-treated seeds and that seeds left to germinate in the streptomycin solution produced seedlings without apparent damage to the roots. These seedlings, when transferred to potted soil, showed no deviation from non-treated plants over a two months period. Embryos of treated cucumber seeds which had been stored for two months still showed the presence of streptomycin when tested on seeded plates.

Ark also treated potato slices, surface inoculated with *Erwinia caratovora*, with a 1–10,000 streptomycin solution one to six hours after inoculation. Check slices rotted in 48 hours, while the treated slices showed very little rot at the end of this period. In field trials, tomato seeds, field contaminated and artificially contaminated with the canker organism *Corynebacterium michiganense*, were soaked for 20 minutes in a 1–10,000 solution. After drying, the seeds were planted in the field along with untreated seeds. The tomato plants from treated seeds showed no canker in 200 plants counted, while the check showed 60 percent canker in a similar count.

Smith (1949) reported encouraging results of seed treatment experiments, using streptomycin sulfate and hydrochloride salts at varying concentrations. Bean seeds carrying the seed-borne bacterial blight (*Pseudomonas medicaginis* var. *phaseolicola*) were immersed in an aqueous solution of the antibiotic for various periods of time. The one hour treatment gave complete control in all dilutions up to 1–1,000; the 15 minutes treatment at 1–500 dilution showed a trace of blight; while a 1–100 solution entirely eliminated it. Plants also remained free from blight when planting was postponed up to 32 days after treatment. Untreated lots in various tests showed an average 25 per cent infections.

Phytotoxic Effects. Aside from inhibition of germination there have been a number of reports of toxic effects when antibiotics have been used in nutrient solutions or as protective sprays. In most cases such reports concern the use of "crude" preparations. In 1947 Anderson and Nienow reported on the effect of streptomycin on higher plants. After germination the seedling roots were immersed and allowed to grow in solutions of streptomycin sulfate in Shives nutrient solution at dilutions of five to 200 μg./ml. Concentrations beyond 50 μg./ml. were toxic to tomato and radish seedlings. Soybeans were not killed, but there was a marked stunting of lateral roots. Wheat, on the other hand, was not injured, even at concentrations up to 200 μg./ml. The characteristic reduction in lateral root development was similar to that obtained from clavacin in earlier studies on corn, bean and onion roots. Soaking eight varieties of seeds for 12 hours in 200 μg./ml. concentrations did not prevent germination, but

when the radish seeds were planted in soil, marked injury (stunting and yellowing) was observed. No reduction in damping off occurred where the seeds were so treated.

Wang in 1948 reported on some of the cytological effects of clavacin on root growth. In this investigation, carried out at the University of Illinois, he used crystalline clavacin supposedly free of all impurities. Concentrations above 1/200,000 in the nutrient solution in which corn roots were growing resulted in the death of the plants. The effect with lower concentrations was similar to that described earlier by Anderson and Nienow, namely, marked reduction in the growth of lateral roots and general stunting of the plants. Even at 1/1,000,000 the growth rate was noticeably reduced compared to the controls.

Viridin

An antifungal substance, different from gliotoxin, has been reported by Brian and his co-workers to be produced by certain strains of *Trichoderma viride* (Brian and McGowan, 1944; Brial et al., 1946). The purified substance, viridin, prevented germination of various spores; among these were the pathogens *Colletotrichum lini* and *Fusarium caeruleum*. Like gliotoxin, viridin is unstable in aqueous solutions except at low hydrogen ion concentrations. Van Der Laan (1948) tested this material on tobacco leaves but found only slight inhibition of *Cercospora nicotianae*.

Antimycin

Leben and Keitt in 1947 announced the discovery of an antifungal substance from *Streptomyces* species, especially effective against a wide range of phytopathogenic fungi and some bacteria. The antibiotic was obtained in a relatively concentrated form by ethanol extraction and subsequent fractionation. This crude preparation inhibited growth of *Venturia inaequalis* at 1/800,000. In greenhouse tests, infection of apple leaves was prevented or greatly reduced by a single spray application of an ethanol solution four hours or four days prior to inoculation with *V. inaequalis*. Later these authors reported on further greenhouse tests, using the material in a 25% ethanol solution and a water suspension to avoid phytotoxic effects (Leben and Keitt, 1948*a*). Complete control of apple scab and early blight of tomato was obtained by using a preparation containing three to six arbitrary units per ml. Artificial rain tests indicated good tenacity. Yields of three to five units/ml. of the active material were obtained in tank fermentations. A more detailed account was presented by these workers on the production, purification, properties and in vitro activity of this substance which was designated as " antimycin " (Leben and Keitt, 1948*b*). A " unit " was established by using a standard ethanol solution which on filter pads gave a zone of inhibition of from 16 to 18 mm., using *Glomerella cingulata* as a test organism. A potency of one unit per ml. was arbitrarily assigned to this standard. A dry solid was obtained by precipitation of a concentrated ethanol solution with water and drying the precipitate in vacuo. Using an agar dilution method, they determined the " inhibition point " of a large number of plant pathogens. Among the most sensitive were *Venturia inaequalis, Sclerotinia fructicola, Phoma lignum, Chalara quercina, Glomerella cingulata* and various species of *Colletotrichum*. *Fusarium oxysporum* (several forms) and a *Pythium* species required high concentrations for inhibition.

In 1949 Dunshee, Leben, Keitt and Strong reported further work on the purification of antimycin. They obtained a crystalline substance from the crude material previously described and, since there was evidence of several other anti-

biotic factors in the crude preparation, they named the crystalline material "antimycin A". It was determined as an active nitrogenous phenol with the probable molecular formula $C_{28}H_{40}O_9N_2$. Weight for weight, it was less active than the crude preparation previously described. Leben and Keitt (1949) extended their studies of antimycin as a protective fungicide. In some tests they used the crystalline antibiotic, antimycin A, but in most of the experiments the crude preparations were used, since these seemed to have greater antifungal activity than the crystalline preparations. In greenhouse tests, both apple scab and tomato early blight were controlled by application of the crude antibiotic at concentrations non-toxic to the foliage. Tenacity tests showed that the crude preparations had fair retention under artificial rain but that crystalline antimycin A was readily washed from the leaves. By using circular discs from the sprayed leaves comparable to the filter pad method, it was determined that a gradual loss of activity occurred with the passage of time; for example, in one experiment over 50 percent of the activity was lost in four days. These authors conclude that these antibiotics may prove useful as protective fungicides, especially in the crude form, provided that cheaper methods of production can be worked out.

Actidione

Actidione has been more widely studied as a plant protectant than any other antibiotic. It is produced by *Streptomyces griseus,* the actinomycete which synthesizes streptomycin, and both antibiotics can be obtained from the same culture fluids (Whiffen, Bohonas and Emerson, 1946; Whiffen, 1948). Pure crystalline material has been isolated, and the structure of actidione has been determined. The compound is β-[2-(3,5-dimethyl-2-oxocyclohexyl]-2 hydroxyethyl) glutarimide (Leach et al., 1947; Leach and Ford, 1948; Kornfeld and Jones, 1948). It is quite stable in distilled water, especially in the acid region, and is soluble in water, chloroform isopropyl alcohol and some other organic solvents.

The microbiological spectrum of actidione shows it to be fairly specific for some fungi and relatively innocuous against bacteria. Generally most animal pathogenic fungi are resistant to the antibiotic (Whiffen, 1948), but many plant pathogens are readily inhibited. While inhibitory concentrations vary greatly, growth is often prevented at concentrations between one and 20 μg. per ml. *Ustilago tritici* is inhibited at less than 0.75 μg. per ml., whereas, at the other extreme, *Fusarium lycopersici* required 100 μg. per ml. (Tukey, 1948; Gottlieb et al., 1950; Wallen et al., 1950; Vaughn et al., 1949). These results were usually obtained by inoculating an agar medium with either spores or mycelium and recording the growth of mycelium. Wallen and his co-workers (1950) studied the effect of actidione on germination process alone, and observed that not only did inhibition occur with some fungi, as with *Alternaria brassicola* and *Helminthosporium sativum,* but that stimulation of the development of germ tubes sometimes also occurred. At 15 p.p.m. the germination of *Chaetomium globosum* was reduced 50 percent, but the length of the germ tubes was at the same time increased. Even more striking was the stimulation of *Botrytis cinerea* spores at the same concentration, for in this case both the percentage germination and the germ tube length exceeded that of the controls. Greater concentrations of the antibiotic are apparently necessary to inhibit growth than germination.

The properties of actidione in protecting some plants from disease have been recently reported. Felber and Hamner in 1948 observed excellent control of bean mildew at ten p.p.m. with complete eradication of the pathogen. Similar

protection was afforded against rose mildew, but some injury to the host plant was observed (Vaughn et al., 1949; Lund, 1949). Field sprays against *Cladosporium cucumerinum* did not completely protect cucumber, though the control was equal to that obtained with other common fungicides (deZeeuw and Vaughn, 1950). Actidione was not effective against *Sclerotinia fructicola*, which causes brown spot of peach, but was a good eradicant for cherry leaf spot caused by *Coccomyces hiemalis* (Peterson and Cation, 1950). Turf diseases, especially brown patch, are readily controlled by sprays with this material (Vaughn, 1951). The antibiotic showed no promise as a seed treatment for peas infected with *Ascochyta pisi* (Wallen et al.).

The phytotoxicity of actidione must limit its use as an agricultural fungicide on some crops. It has been reported toxic to tomato, peach, bean and geranium (Gottlieb et al., 1950), to peach (Peterson and Cation, 1950) and to roses (Lund, 1949; Vaughn et al., 1949). Its toxicity to other crops has also been observed. Some seeds are sensitive to this fungicide; when treated in solutions of actidione, the germination of cantaloupe, spinach and cucumber were not affected, whereas peas, wheat, radish and kidney bean were greatly reduced (Wallen et al., 1950; Vaughn et al., 1949).

This antibiotic might possibly have some use as a soil treatment in the absence of sensitive host plants. The antibiotic can remain unaltered in sterile soil, since Gottlieb and Siminoff (1950) have shown that it is not inactivated and will inhibit the growth of *Cryptococcus neoformans*. Its activity in soil is also shown by the reduced germination of kidney beans in actidione treated soil (Vaughn et al., 1950).

Musarin

A search for an antibiotic-producing organism which would inhibit *Fusarium oxysporum* var. *cubense*, the cause of banana wilt, was carried out by isolating the microflora from soils in areas where this disease does not occur. By this method, Meredith isolated an actinomycete which was antagonistic to the pathogen (Meredith, 1943, 1944). Plots treated with the antagonistic organisms had less diseased stools than untreated plots. The actinomycete produces the antibiotic, musarin, when grown in liquid culture (Thaysen and Morris, 1947; Thaysen and Butlin, 1945; Arnstein et al., 1948). Essentially pure preparations of this compound have been made, but little information on its chemistry is available. The free acid is insoluble in water, while the sodium salt is soluble. Musarin inhibits the germination of some fungi and bacteria, but results of plant protection tests have not been published.

Alternaric Acid

Alternaric acid is of special significance in plant pathology because of evidence that it might be the chemical agent which is directly responsible for the disease effects in early blight of potatoes. The antibiotic is produced by *Alternaria solani* and has been isolated in crystalline form by three groups of investigators (Brian, Hemming, Curtis, Univin, and Wright, 1949; Darpoux, Faivre-Aimot and Roux, 1950; Pound and Stahmann, 1950). It has little antibacterial activity but inhibits a variety of fungi. This inhibition effect is of two types. Germination of spores of *Absidia glauca, Myrothecium verrucaria* and *Stachybotrys atra* are inhibited between 0.1–1.0 μg. per ml. The spores of other fungi such as *Botrytis allii* germinate in concentrations as high as 200 μg. per ml., but the germ tubes and hyphal extension are stunted in concentrations as low as 0.01 μg. per ml. Alternaric acid is phytotoxic to many plants and on tomato produces symptoms which closely resemble those which occur when the host is attacked by *Alternaria solani*.

Subtilin

Subtilin was first obtained from a strain of *B. subtilis* by Jansen and Hirschmann (1944) and later studied by a number of workers (Salle and Jann, 1945; Lewis et al., 1947; Dimick et al., 1947). According to Dimick and his co-workers, the purified material resembles a peptide. It is relatively stable in the acid range but loses activity at pH levels above 7.0. The antibiotic inhibited a wide range of Gram-positive bacteria. Later Goodman and Henry (1947*a*, 1947*b*) also discovered a strain of *Bacillus subtilis* with antibiotic properties which inhibited *Xanthomonas translucens*. Because one of the many substances produced by strains of *B. subtilis* is subtilin, they tested this antibiotic in vitro and found that it also inhibited growth of the pathogen. Subtilin solutions were then used to protect barley seeds which had been infested with *Xanthomonas*. At the very high dilution of 1:1000 the treatment reduced the disease rating as compared to the untreated plants in both sterile and unsterile soil.

Endomycin

Endomycin, a new antibiotic of potential value for plant disease control, was first reported in full by Gottlieb, Bhattacharyya, Carter and Anderson in 1951. This material inhibits a wide range of filamentous fungi, which are pathogenic to plants and animals, as well as yeasts and bacteria. Relatively pure preparations inhibit the growth of fungi in vitro at concentrations from 1 to 50 μg. per ml., depending on the species and strain, and compare favorably with most commercial fungicides. Apparently the sensitivity of bacteria to this compound varies greatly, since a number of the Gram-negative species can tolerate 100 μg. per ml. Among the sensitive plant pathogenic fungi, those inhibited below 25 μg. per ml. are *Sclerotinia fructicola, Rhizoctonia solani, Glomerella cingulata, Colletotrichum phomoides* and *Fusarium lycopersici*. The only bacterial plant pathogen tested, *Agrobacterium tumefaciens,* was inhibited at 10 μg. per ml.

As with many other antibiotics, endomycin is produced by an actinomycete, *Streptomyces endus*. It can be extracted from both the fermentation liquor and the mycelium of a growing culture with butanol. No information is available on the intimate chemical nature of this compound, other than that it is a weak acid. In the acid form, endomycin is soluble in alcohols and methyl cellosolve and is sparingly soluble in dioxane and water. Non-polar fat solvents, such as ether, chloroform or benzene, do not dissolve the material. When changed to a salt, however, endomycin is soluble in water. It is stable to heat: 121° C. for 15 minutes, or 100° C. for one hour. No inactivation occurs in the pH range of 1.0 to 11.5 at 20° for 24 hours.

The toxicity of endomycin is low; when it is sprayed on wheat, tomatoes and beans at 10,000 p.p.m. under greenhouse conditions no injurious effects occur. Leaf rust of wheat is entirely prevented on plants sprayed with 1000 p.p.m. At 100 p.p.m. and 10 p.p.m. the infection is partially controlled, 90 and 50 percent, respectively (Gottlieb, 1951).

Helixin

This antibiotic appears to be identical with endomycin. Data from both paper chromatography and biological activity as well as their isolation characteristics are similar (Leben, 1952). In agar streak tests, it too inhibited a wide range of plant pathogenic fungi at concentrations less than 15 μg. per ml. (Leben, Stessel and Keitt, 1951). Especially interesting are the studies on the use of the compound as a protective fungicide (Leben and Keitt, 1952). The hydrogen ion concentration of the spray influences its protective action. When tomato leaves were sprayed with a solution of

45 μg. helixin per ml. at a pH of 3.0 and 6.0, the control of *Alternaria solani* was 70.7 and 96.3 percent, respectively. On the other hand, the tenacity of helixin on the foliage was better if the compound was applied at the more acid level.

Fungocin

Bacillus subtilis and *B. mesentericus* are the sources of still another antifungal and bacterial agent, fungocin (Cercos, 1948, 1949). This has been isolated in relatively pure form and appears to be a polypeptide similar to but not identical with bacillomycin and eumycin and antibiotic XG (Cercos, 1950). It is soluble in water, methyl, ethyl and butyl alcohol, slightly soluble in methyl acetate, almost insoluble in acetone and insoluble in ethyl ether, chloroform and benzol. It is precipitated with NH_4SO_4, copper sulfate, zinc sulfate and lead acetate. Aqueous solution gives a Heller ring, Millon and Xanthoproteic reaction. Fungocin is very stable to heat and is only slightly inactivated by autoclaving. At room temperature it is stable to alkali and acid but loses some activity when boiled at pH 2 or 10 for one hour.

A concentration of two μg. of fungocin per ml. of broth inhibited all 12 of the plant pathogenic fungi which were tested; when it was dissolved in agar, however, greater concentrations were necessary. Gram-negative bacteria were not inhibited at low concentrations. When wheat seeds were soaked in solutions of the antibiotic, as little as 0.2% inhibited the development of rootlets and root hairs (Cercos, 1951*a*). Though a number of experiments on the control of *Ustilago maydis* on corn and *Helminthosporium sativum* on wheat have been reported in detail, these studies were not made with extracted material. Liquid cultures of the bacteria were mixed with spores of the two fungi before inoculating the host plants. The control of disease in these instances could conceivably have been caused by other factors than the antibiotic in the broth (Cercos, 1948). On the other hand, Cercos (1950*b*) presents good pictorial evidence for the use of fungocin for control of *Phytophthora infestans* on potato; plants which were first sprayed with a solution of the antibiotic remained vigorous after inoculation with the pathogen, while the control plants were completely killed.

Toximycin

Though only a preliminary report on toximycin is available, its use in plant pathology has been intensively studied (Stessel et al., 1952). It is another of the *B. subtilis* groups of antibiotics and is apparently unique. Partially purified material inhibited 20 fungi and three bacteria at relatively low concentrations. Spraying tomato plants with solutions of 300 μg. per ml. resulted in good control of *Alternaria solani* infections. Solutions of the antibiotic were not toxic when used as a spray but were deleterious when taken into the plant directly. Tomato cuttings wilted in solutions of toximycin alone at concentrations above 2.5 units.

Antibiotic XG

Antibiotic XG obtained from a *Bacillus subtilis* type organism was reported by Wallen and Skolka (1950) to be effective in the control of leaf and pod spot caused by *Ascochyta pisi* when used as a seed treatment. In vitro inhibition occurred at all concentrations above one p.p.m. In the laboratory, pea seeds internally infected to the extent of 14–15.5 percent with *A. pisi* were soaked for 18 hours in 25 p.p.m. The infection was reduced to zero in one case and to 4.5 percent in another. No reduction in germination was noted at this concentration, but germination was impaired at higher concentrations. When the treated seeds were germinated in the soil, no impairment occurred at 50 p.p.m. and complete control was obtained.

Griseofulvin

Recent studies of the absorption of griseofulvin by plants and its protective action as a systemic fungicide has focused attention on this unusual material. It was first isolated and identified by Oxford, Raistrick and Simonart in 1939 and was of interest only as one more metabolic product of the fungi. Seven years later Brian and his co-workers isolated an antifungal factor from *Penicillium Janczewskii* named "curling factor" (Brian, Curtis and Hemming, 1946) which was subsequently shown to be identical with griseofulvin (Grove and McGowan, 1947; Brian, Curtis and Hemming, 1949). An unusual and rather characteristic effect of this antibiotic is the curling of young hyphae of *Botrytis allii* at extremely low concentrations, i.e., 0.2 μg./ml., while high concentrations, even of 100 μg./ml., do not prevent germination of the conidia. Even though the spores germinate at high concentrations, the germ tubes are stunted and a mycelium never forms. These odd effects occur with many fungi and are correlated with the presence of chitin in their cell walls.

Griseofulvin is one of the rare groups of natural compounds which has an organic chloride in the molecule. It is a crystalline compound with the formula $C_{12}H_{17}O_6Cl$ and a melting point of 220° C. The optical rotation is very high $[\alpha_D^{17}] = +370°$ (McGowan, 1946). The pure compound is soluble in acetic acid, dioxane, benzene, ether and ethyl alcohol but only slightly soluble in ligroin. It is also very stable to heat. In 1951 Grove et al. published a revised structural formula for this material.

Brian (1949) has shown that griseofulvin reduced the growth of 39 species of fungi 50 percent at low concentrations usually under 20 μg./ml. The fungi which were not inhibited in this manner were ten oomycetes, two yeasts and one basidiomycete. Even at low concentrations, 0.2 μg./ml., in which morphological changes of the hyphae are not severe, a reduction in growth occurs. The effects on mature mycelia are not caused by any inhibition of oxygen uptake in the presence of griseofulvin.

That griseofulvin can be absorbed by roots and translocated in plants has been demonstrated in the studies of Brian and Wright (1951). Oat, lettuce and tomato seedling can remove the antibiotic from nutrient solution or soil containing ten to 50 μg./ml. Griseofulvin can subsequently be found in the leaves or in guttation drops, even if the plants are removed and transferred to fresh nutrient solution. When plants are grown either in a nutrient solution containing the antibiotic or in soil watered with antibiotic solutions and then inoculated with plant pathogens, the disease is greatly retarded. Lettuce plants, when grown in water culture containing ten μg. of the antibiotic per ml., then sprayed with spores of *Botrytis cinerea*, had only 40 percent of the plants infected compared to 100 percent infection of the controls. Such results with antibiotics are extremely important in encouraging more intensive research in systematic fungicides, a branch of plant pathology which is only in its infancy at present.

Antibiotics in Soil

The discovery of antibiotics has given impetus to a review of the problem of the biological control of soil-borne pathogens. Almost all the conclusions that antibiotic-producing organisms can be important in this field have been derived from studies which showed that an antibiotic-producing organism, when added to soil, controls disease; but no antibiotic has been isolated from soil. In three instances, however, antibiotically active solutions have been obtained from soil in which organisms producing well-defined antibiotics had grown. Grossbard (1948, 1948*a*, 1949) demonstrated a ma-

terial, presumably patulin, in soils to which carbohydrates or plant materials had been added and then infested with *Penicillium patulum*. Gottlieb and Siminoff (1950) have found similar antibiotic activity in unamended soils which had been infested with *Aspergillus clavatus*. More recently the production of an antibiotic has been shown when *Streptomyces venezuelae* was added to sterile unamended soils. Qualitative studies of its chemical and biological activity indicate that the antibiotic probably is chloromycetin (Gottlieb and Siminoff, 1951).

Summary

Compared to the wide use of antibiotics in human therapy, their absence in plant therapy is at first glance surprising. When one examines the reasons for this situation, a number of explanations are obvious. First, most of the search for new antibiotics has been carried out for the purpose of curing human diseases; the purified materials were then only incidentally tested against plant pathogens. Second, many plant pathologists realized that the high cost of such materials, while not limiting their use for the saving of human lives, would exclude their use in the control of plant diseases, especially when many synthetic fungicides were available. Nevertheless, the stimulus to further antibiotic research in plant pathology is the occurrence of certain types of diseases which cannot be controlled by the usual inorganic and organic fungicides, such as diseases caused by bacteria on leaves or stems, and root rots or seed decays caused by soil-borne bacteria and fungi.

As indicated in this review, none of the antibiotics which have been studied shows promise for general use, though each might find limited application. The bacterial inhibitors streptomycin and penicillin have been successfully used in a few instances, as against crown gall and the necrosis of giant cactus, and also might be useful as seed treatments against bacteria and even some fungi. Gliotoxin, an antifungal agent, was effective as a seed protectant, but it was generally inferior to the organic mercury compounds; furthermore it is a very unstable material. Antimycin was effective in controlling both apple scab and apple blight. This material has not been produced commercially and its cost might be prohibitive for general use. Actidione is apparently a superior fungicide for some specific diseases but most probably will not be a general fungicide because of its toxicity to some host plants. Since it is a by-product of streptomycin fermentation, actidione most probably could be produced at a cost which would permit its use.

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BOOK REVIEWS

The Origin, Variation, Immunity and Breeding of Cultivated Plants—Selected Writings of N. I. Vavilov. Translated from the Russian by K. Starr Chester. Chron. Bot. Vol. 13, No. 1/6 (pp. viii + **366**). **1951.** Waltham, Mass.: The Chronica Botanica Co.; New York City: Stechert-Hafner, Inc. **$7.50.**

In 1883 Alphonse de Candolle published his " L'origine des plantes cultivées ", and so careful and painstaking was the labor behind this book that it has been regarded ever since as the classic on the history of cultivated plants from a world-wide viewpoint. The conclusions of that great study were founded upon an imposing variety of evidence which did not, however, include the evidence offered by studies on the anatomy, genetics, cytology, distribution and diseases of the plants concerned. It remained for a later generation to give consideration to these aspects of the problem, when, in the 1920's, the Soviet All-Union Institute of Plant Industry conducted a world-wide search for breeding material useful in producing food crops for the Soviet Union. In pursuing this investigation, expeditions were sent to 60 countries in Europe, Asia, Africa, North America, Central America and South America, and some 300,000 samples of seed and seedling material, in addition to a tremendous mass of information, were assembled.

The guiding spirit behind this great work was N. I. Vavilov who, as one-time President of the Lenin Academy of Agricultural Sciences and Director of the Institute of Applied Botany, was instrumental in establishing and directing more than 400 research institutes and experiment stations with a staff of 20,000 in the years from 1921 to 1934. During part of this time he participated in expeditions to Afghanistan, Abyssinia, China, Central America and South America, where he collected economic plants, including 26,000 strains of wheat. In addition, he did extensive writing, in Russian, and the climax of his career was marked in 1935 " by publication of the 2500-page symposium, 'The Scientific Bases of Plant Breeding', of which Vavilov was editor and principal author. Here, in their last and most complete form, are given Vavilov's contributions on the origin of cultivated plants, the law of homologous series in variation, the immunity of plants from diseases and the scientific bases of wheat breeding. Vavilov had hoped to translate at least a part of these contributions into English for the benefit of his many English-speaking fellow scientists and friends, but this was prevented by his untimely death, and, until the present, these classics of botanical-agricultural literature, in their mature form, have been printed only in the Russian language ".

Unfortunately for him but fortunate for the scientific world, Vavilov was a geneticist and plant-breeder of the old school. When the academic furor arose in Soviet Russia concerning fundamental doctrines of biology, he was on the losing side and very likely was " liquidated ", probably in the early months of 1942. At any rate, he was not heard from after that, and his writings, since they had not yet been translated and published, were of value to only a few biologists outside the Soviet Union. It is therefore a long awaited and valuable contribution that Dr. Chester and the publishers of this present translation have made in now offering in English and in full, all of Vavilov's writings that formed a part of the symposium referred to above.

While all six writings of Vavilov that make up this translated edition deal with economic botany in a broad sense, particular interest for readers of ECONOMIC BOTANY attaches to his " Phytogeographic Basis of Plant Breeding ". In this chapter he gives important conclusions resulting from the extensive and systematic geographic investigation by the Institute of Plant Industry on a great number of field, vegetable and fruit crops, and bemoans the fact that " the vast continents of South America and Africa, India, China, Indo-China, and Western Asia have been studied but little ". Nevertheless, he goes on to say:

" But from the incomplete data which we now possess on the vegetation of the earth, the important fact of the geographic localization of the process of species formation has been made clear. The geography of plants shows definitely that in modern times the distribution of plant species on the earth is not uniform. There are a number of regions which possess exceptionally large numbers of varieties. Southeastern China, Indo-China, India, the Malay Archipelago, southwestern Asia, tropical Africa, the Cape regions, Abyssinia, Central America, South America, southern Mexico, countries along the shores of the Mediterranean, and the Near East possess extraordinary concentrations of plant varieties. On the other hand, the northern countries—Siberia, all of central and northern Europe and North America—are characterized by a poverty of varieties ".

" Central Asia is surprisingly rich in varieties. Within the Soviet Union, from Crimea towards Transcaucasia and the mountainous regions of Central Asia through Altai and Tian-Shan, the number of varieties markedly increases. It reaches its peak in the Caucasus and the mountains and foothills of Central Asia. Here the number of species is very great for a given area. The concentration of species in these regions is ten times greater than in Central Europe and still greater when compared with the northern regions ".

" In some parts of the world, the concentration of varieties is remarkable. Thus, for example, the small republics of Central America, Costa Rica and Salvador, have areas about one hundredth of that of the United States, yet they possess a number of species as great as is found in all of North America, i.e., in the United States, Canada, and Alaska combined ".

It must be borne in mind that these conclusions and all others on the distribution and origin of cultivated plants emanating from the Soviet work were not the primary objective of that work, they were incidental to it, the primary objective being to find and bring home genetically valuable breeding stock. One is particularly apt to lose sight of this when considering the details of the conclusion that there have been " eight ancient centers of origin of world agriculture or, more exactly, of eight independent regions where various plants were first cultivated ". These are as follows:

a) The Chinese Center—" The earliest and largest independent center of the world's agriculture and of the origin of cultivated plants consists of the mountainous regions of central and western China, together with the adjacent lowlands ". One hundred thirty-six species, including a few groups of varieties, are listed for this center.

b) The Indian Center, exclusive of northwest India, Punjab and the Northwest frontier, but including Assam and Burma. One hundred seventeen species listed here. A subdivision of this center is given as the Indo-Malayan Center, including Indo-China and the Malay Archipelago, and accounting for 55 kinds of plants.

c) The Central Asiatic Center. Includes northwest India (Punjab, the northwestern frontier provinces, Kashmir), all of Afghanistan and the Soviet Republics of Tadjikistan, Uzbekistan and western Tian-Shan. Forty-two kinds of economic plant.

d) The Near-Eastern Center, including the interior of Asia Minor, the whole of Transcaucasia, Iran and the highlands of Turkmenistan. Eighty-three species.

e) The Mediterranean Center. Eighty-four species.

f) The Abyssinian Center. Thirty-eight species and groups of varieties.

g) The South Mexican and Central American Center. Forty-nine items.

h) The South American (Peruvian-Ecuadorian-Bolivian) Center. Forty-five items. Two subdivisions are given as the Chiloe and the Brazilian-Paraguayan Centers, accounting for 17 kinds of plants.

" From the lists given above ", says Vavilov, " it seems apparent that an overwhelming majority of the cultivated plants had their origin in the Old World. Of the 640 most important cultivated plants listed, over 500 belong to the Old World, i.e., 5/6 of the cultivated plants of the world. The New World contributed approximately 100 plants ".

Two other features of Vavilov's interpretation of the great mass of data assembled under his direction merit mention here. One is his recognition of so-called secondary centers of origin and that many of our cultivated plants had a diversified instead of a

single origin. The soft wheats, for instance, came from southwestern Asia, while the hard wheats originated in the Mediterranean region; and maize, originating in the South Mexican and Central American Center, developed groups of waxy varieties in the Chinese Center. The result is that many kinds of plants are listed in two of the eight world centers. The other feature is Vavilov's recognition of so-called primary and secondary crops. The first, to which belong wheat, barley, corn, soy bean, flax and cotton, " consists of plants cultivated from ancient times and known only in cultivation or in wild state. The second group consists of all plants which have been derived from weeds which grew among the basic primary plants ". In areas favorable to the primary crops, these weeds were of little importance, but in unfavorable regions they gradually replaced the primaries. Such was the development, for instance, of rye and oats.

Had Vavilov been spared his untimely death, the botanical world concerned with the economic aspects of plant life might have been enriched by valuable contributions from this man other than those offered in this excellent translation to the English-speaking world.

The Chemistry and Technology of Food and Food Products. Morris B. Jacobs and collaborators. 3 volumes. 1951. Vol. I: $12; Vol. II: $15; Vol. III: $15. Interscience Publishers, Inc.

This second edition, completely revised and augmented (not second revised edition as the title page misleadingly states), is the work of 39 collaborators under the editorship of Dr. Jacobs who has long been prominent in the chemistry and technology of foods, and constitutes an encyclopedic work of about 2,500 pages on the subject. The first edition, published in 1944, comprised two volumes, but in this new edition a third volume has been added. The first and third volumes are devoted to the chemistry, processing and other technological aspects of food products, but Volume II, in addition to its consideration of dairy products, meats and seafood, includes chapters, totaling 660 pages, on cereal grains, vegetables and mushrooms, confectionery and cacao products, coffee and tea, and flavors, spices, condiments and essential oils. These chapters alone, if lifted from the volume, would constitute a worthy reference work on vegetable foods, and along with vegetable-product information scattered through some of the other chapters, the three volumes offer a most valuable asset for any technological, chemical or general reference library.

A History of the Hemp Industry in Kentucky. James F. Hopkins. xiv + 240 pages. University of Kentucky Press. 1951. $4.

In the colonial days of America and the first 80 years of the succeeding new Republic, while sailing vessels were in vogue, hemp fiber was a commodity of importance, for it was the material out of which sails and cordage for shipping were made. The coarsest of clothing, too, was made from it, as well as bagging for the cotton produce of the South. In the early days English shipping was dependent for this material upon the Baltic countries, but, always threatened by the possibility of those supplies being cut off, British and colonial shipping interest looked to America as a possible new source of the fiber. Various forms of encouragement—bounties and legislative orders—were promulgated to stimulate American production of the fiber. Some success attended these efforts, and after the Revolution, the industry spread beyond the Alleghanies.

In this development Kentucky became one of the principal hemp-producing States, and the history of that development, from its beginning through its decline, has been sifted from hundreds of sources and presented in this volume. In that State, as well as elsewhere, " hemp was important to the farmer who produced the fiber, to the manufacturer who transformed it into cordage and coarse cloth, to the commission merchant who sold the finished product locally or in other areas, and to the politician who had always to bear in mind the interests and desires of his constituents ". In 1810 Kentucky contributed all the hemp reported, " three-fourths of the crop of 1840, one-half of the yield in 1847 and in 1849, and about one-third the total production of 1859. Most of the hemp outside her borders grew in Missouri, which in 1849 produced slightly less, and in 1859 slightly more, than Kentucky ". According

to the Patent Office, " 30,000 tons of hemp, 'not a large crop', were produced in the United States in 1847, and fully half of the total grew in Kentucky ".

After the Civil War, with the advent of steel shipping, no longer needing so much cordage, and with the introduction of jute and Manila hemp as sacking and cordage fibers, respectively, the hemp industry declined, except for war-time revivals, until today it is non-existent in Kentucky. In 1917, when imports from Russia and Italy had been cut off, Kentucky probably produced over 7,000 of the 20,000 tons of domestically grown hemp harvested that year; and in 1942, when the War Production Board approved plans for planting 300,000 acres of hemp and erecting 71 mills for cleaning the fiber, sites were selected for 42 mills in various States, only one of them in Kentucky. Today the industry no longer exists in that State, but its history there is well recorded in this volume.

Soybeans and Soybean Products. 26 authors; edited by Klare S. Markley. 2 Vols., 1145 pages. Interscience Publishers. 1950/1951.

It is perhaps safe to state, without fear of contradiction, that no other crop plant has found such a vast diversification of industrial utilization as has soybean. Used as food in China for centuries, it appears to have been first cultivated in the United States about the beginning of the nineteenth century, but has never become popular in this country as a food, except in processed form. In such processed forms and in other products that it provides, it is perhaps without rival, and an enormous literature and technology have developed with regard to its utilization. This literature and technology are scholarly recorded in these two volumes of more than eleven hundred pages. The first volume, among other features, is devoted to the history, production, chemical and physical properties, and processing of the crop; the second concludes the consideration of processing and then devotes nearly 500 pages to all aspects of utilization.

Oil is the principal product obtained from the beans, and in 1946 domestic production of it amounted to 1,454 million pounds. The edible products manufactured from the oil are shortening, margarine and salad oils; non-edible outlets include paints, varnishes and enamels, inks and stains, sealing and caulking compounds, linoleum and oilcloth, and core oils. At present four commercially important byproducts are recovered from the oil—lecithin, soapstock or foots from alkali refining, steam deodorizer distillates and molecular distillates.

" Originally soybean lecithin was regarded as an undesirable sludge, and the main problem was to dispose of it without creating a nuisance. . . . Within a short space of 20 years thousands of industrial applications have been found for this interesting residue, and research continues unabated to find even more uses. However, at present over 80% of the lecithin produced in hydrated form is not recovered because no uses can be found for this additional huge amount that could be recovered. The total production of soybean lecithin in the United States is estimated at 8 million lb. in 1948, while about 40 million lb. which could be produced is not recovered. From these figures it is evident that the problem of utilizing the potential American lecithin production remains to be solved. The tremendous present and potential production of lecithin has caused the price to drop from about 75 cents per pound 20 years ago to about 15 cents per pound today ". The outlets for this over-abundant product are the food industry, antioxidants, pharmaceuticals, paints and printing inks, rubber and petroleum, leather and textiles, and cosmetics.

The three most valuable materials in the other three fractions mentioned above are fatty acids, sterols and tocopherols. Each of these has specialized avenues of utilization. And then, after the oil and its byproducts are extracted and disposed of, there remains the meal—to the extent of about four million tons in 1949—which serves as feed for livestock and poultry. After that there is the huge field of soybean protein products.

Each of these well-developed fields of utilization is extensively discussed, and the discussion, along with that on the technology of the industry and the hundreds of citations in footnotes throughout the two volumes, provide an account of this one crop such as few others have received.